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WOOD AND ITS USES:

A HANDBOOK

FOR THE USE OF

CONTRACTORS, BUILDERS, ARCHITECTS, ENGINEERS,

TIMBER MERCHANTS, ETC.

WITH INFORMATION FOR

DRAWING UP DESIGNS AND ESTIMATES.

AND

UPWARDS OF TWO HUNDRED AND FIFTY ILLUSTRATIONS.

BY

P. B. EASSIE,

Member of the Institution of Mechanical Engineers.

GLOUCESTER:

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WOOD AND ITS USES.

CHAPTER I.

TIMBER AND DEALS.

Chief kinds, from whence imported, Marks and Qualities, Conversion by Sawing, Prices of Scantlings from the Deal, Boardings and Scantlings from the Log.

AS the chief substance forming the manufactures treated of in this work will be of wood, we consider it our duty to state the principal features of those kinds used in building generally, and the places from whence we derive them. From the natural form of a tree, its easy manipulation into beams and girders, the combination and framing of which enables us to raise structures of all kinds quickly, timber enters largely into everyday use. No seasoning by desiccation or other such processes is equal to natural seasoning, by being exposed to the atmosphere, and house fittings of all kinds can only be properly produced by those who keep large stocks in hand, used only three or four years after its conversion. For engineering purposes its decay from the white ant, the teredo worm, and disease and decay generally, is counteracted by saturation with Corrosive Sublimate, called Kyanizing, or with Chloride of Zinc, called Burnetizing, or by impregnating it with Creosote, called Creosoting. The last process is the most common. When wrought in houses it is usually preserved by painting with oil-paint, and care should always be taken to paint also the joints before putting together. The chief hard woods used are Oak, Ash, Elm, Teak, and Mahogany; and of the resinous woods, Red Pine from Norway, Sweden, and Russia; Memel, Dantzic, and

Riga Fir from Russia and Prussia; Yellow Pine from Canada, Pitch Pine and Cedar.

HARD WOODS.

OAK is the hardest and most durable of all trees; it is a native only of temperate countries, and grows very slowly. Those kinds chiefly imported into this country are Riga and Stettin Oak from Russia, and Quebec Oak from America. None of them are equal in strength or durability, however, to the native English Oak. Riga Wainscot Oak is divided into three qualities, viz.—English Crown C, Dutch Crown H, and Common or brack quality W.

ENGLISH ELM wood is very hard, flexible, and tough, and difficult to work, will stand well if kept constantly wet, hence it is largely used for keels of vessels, wet foundations, for piles, pumps, &c. Its toughness makes it useful also for wheel naves and rims, and general wheelwright's work. Wych Elm is preferred for bending purposes by coachmakers.

ENGLISH ASH, again, is superior to any other English timber or toughness and elasticity. Used extensively in wheelwright's and shipbuilder's work, it is also largely used for walking sticks and spade handles, when from three to ten years' growth only, and indeed its branches at all stages of the tree's existence, come in for hop poles, crates, basket-handles, hurdles, &c. It is tough and elastic, and thus becomes serviceable in all implements of husbandry, tools and the like.

MAHOGANY has been an import into this country for 150 years. The finest is obtained from Domingo, the next in quality from Cuba, and the next best from Honduras, the latter being better known as Baywood. Its price prohibits its use beyond furniture, and doors for rooms, and in cotton mill machine frames. The Spanish Mahogany runs from 20 to 26 inches square, and about 10 feet in length. Honduras is from 2 to 4 feet square, and 12 or 14 feet long.

TEAK WOOD or INDIAN OAK comes chiefly from Malabar, as well as Java, Ceylon, and other parts of the East Indies. It is largely used in shipbuilding, and as it seldom shrinks it is often used in panels of coaches.

AFRICAN TEAK or AFRICAN OAK comes from Sierra Leone; is used in shipbuilding, from its being very hard, dense, and brittle; it is most difficult to work.

RESINOUS WOODS.

CEDAR WOOD is extremely durable, and specimens have always been found in temples of the greatest antiquity; it is straight grained, easily worked, but readily splits; it is a native of Spain, the South of France, and the Levant. The Bermudan Cedar is used for internal joiner's work and furniture. The Red Cedar, used in pencils, is a native of North America and the West Indian Islands, and is largely used for drawers, wardrobes, church furniture, &c.

RED or YELLOW PINE is the same as the Scotch Fir or Wild Pine; the best coming from the North of Europe, in the shape of logs, deals and spars. The Riga and Norway is the best, but Memel is little, if any, inferior. The Swedish timber is inferior to all others of this class. The timber trees of Sweden and Norway are felled regardless of size and quality, the finest are selected for deals or hewn into square timbers, the smaller sizes are converted into boards or battens and mining timber; next come the short, square, or round logs for sleepers, which since the disuse (owing to the scarcity) of Scotch or English Larch, is now a trade of gigantic proportions, especially at Dantzic. Pit props and telegraph poles use up the remainder; when below 2½ inches at the top, the poles are sold as "rickers," and still smaller, as spars. That coming from Memel is divided into three qualities, viz.:—crown 13 × 13 from 28 to 50 feet, best, middling, and second middling, or brack.

Dantzic Baulks are from 14 to 16 inches square, and 40 feet long average. Crown still larger.

RIGA FIR is 13 inches to 14 inches square, and 40 feet average; when used as beams it should be sawn longitudinally and the ends reversed, as the heart is often shaky, which can, by this means, be tested. Riga also sends us a considerable number of masts and spars, 18 to 25 inches diameter, and 70 to 80 feet long, those of less than 18 inches being called spars. Planks and deals of this timber, from all ports, are largely sent to this country.

RUSSIAN RED TIMBER is sent us also as lathwood. Trees from 9 to 12 inches diameter are cut into lengths of 6 or 8 feet and split into segments, the heart wood is then riven off and left in the forests as firewood. In Southern Russia fir trees will attain a diameter of 2 feet in 50 years.

WHITE FIR or DEAL is the produce of the Norway Spruce; the spars are from 50 to 60 feet long and 6 to 8 inches thick, chiefly used for scaffold poles, ladders, oars, and small masts. American Spruce is inferior in quality, but both are imported in the shape of deals, planks, &c. Young trees from Christiana are sent also here as scaffold poles, some growing so rapidly as to be 50 or 60 feet long, without a branch.

AMERICAN WHITE or YELLOW PINE is imported in large logs, it is well fitted, when seasoned, for all joiner's work and mouldings. In America it is used largely for shingles to cover houses. It makes excellent masts. The best class of Pine is that shipped from Quebec, and the best class of Spruce that sent from St. John's. Rafted or floated Deals are shipped from all Canadian ports except St. John's, and this creates a value in their favour, as they are thus *bright* or unwatered. The floating of timber damages the goods. 1st. It discolours them, especially the sappy parts, makes them gritty; and 2nd. They are apt to crack in drying. *Bright* Deals on the other hand, if shipped in good condition, will reach this country as clean as when first sawn. Best Canadian timber in baulk is known as *Waney* and *Board* Pine; an inferior quality being known as *Building* timber.

PITCH PINE is a native of Canada, and large quantities are shipped from Florida and Pensacola; its elasticity is remarkable. It is much used for deck planking, pumps, and troughs.

As stated before Red and Yellow Pine, White Fir or Spruce, and American White or Yellow Pine, and Pitch Pine are largely imported in planks, deals, battens, &c. They are called *planks* when over 11 inches wide, *battens* when 7 inches wide and under, and *deals* when between 7 and 11 inches wide. They vary in thickness from 1 to 4 inches, and the following are the chief sizes, viz.:—

11 × 4	11 × 3	9 × 2	7 × 1½	7 × 1¼	7 × 1
9 × 4	9 × 3		9 × 1½		8 × 1
	7 × 3		8 × 1½		

In American Yellow, Pitch Pine, and Spruce, the widths may run as high as 18 inches to 2 feet, though seldom in the two latter kinds.

Planing machinery having been largely introduced in Sweden and the Baltic ports, they often also import flooring 1 inch and 1¼ inch thick, ready prepared, and even mouldings.

Deals are often branded with a variety and number of trade marks, chiefly denoting the quality. Strange, a crown has been used from time immemorial over whole continents from which we derive our supplies, and we append a short list of the principal marks used on red deals, with the port from which they are shipped in Norway, Sweden, and Russia.

NORWAY.

CHRISTIANA.

1st.	2nd.	1st & 2nd Mixed.	3rd.	4th Quality.
A × T	A × H	I M	A C	
H H	A H S	H R H	A W	
H P W	B H F	W M E	A W W	
H × W	C × S		B	
L M	F H B		D L D	
M S	F V B		H × H	
N × S	H & S		H T W	
P M A	H y S		M H M	
S I B	H M S		R B	
T I H & S	H S W		S × S	
V E D	L B		T R B	
W F I	P × W			
	R R B			

DRAMMEN.

E × E	A 3 S	A N	A A	K
E ix E	A N 2	T A B B	A × B	
E viii E	B		A 3 B	
viii E	C & C°		A H	
I B	viii E		C C	
J I R	H K & C°		E	
M }	I		E E	
♛ }	I I		E × E	
	I × E		H	
	I E I		H C	
	I R P		H × H	
	I 2 S		H K	
	J 2 R		I E	
	K 2 S		I I	
	K W		I I R	

DRAMMEN.—*Continued.*

1st.	2nd.	1st & 2nd Mixed.	3rd.	4th Quality.
	M × N		I W	
	N ii		J I I	
	N J		J 3 R	
	N M		K 3 S	
	S — C		L L	
	T ✱ M		L — L	
	T × T		N A M	
	X X		N B	
			N iii B	
			N xxx	
			P	
			R iii	
			S C	
			S × C	
			T B	
			T M	
			T T	
			W D	
			✱	
FREDERIOSTADT.				
A K° C°	A K C°	A T & C°	C × S	H B F
H ✱ B	B × B	F S M	F S C	
J B	K × K		G	
J N J	M M		H B T	
S F A	S F B		S W S	
W ♛ B	W W			
W ♛ ♛ G				
W I E L & C°				
W I E S				
LAURVIG				
F W T }	F W T		T 3	
F W T }	T 2			
F W T }	X X			
T I }				
SKIEN PORSGRUND, KRAGERO, AND THRONDJEM.				
I N I	C 2 S	H B	H B K	
	H G	H B J	H × C	
	L × M		H H	
	N × W		N × V	
	T × T		V G	
	V B		V V	
			W W	

SWEDISH PORTS.

GOTHENBURG.

1st.	2nd.	1st & 2nd Mixed.	3rd.	4th Quality.
		A L O	A × O	L × O
		C F W	C × G	× M ×
		D B & C°	× C ×	S S
		H ✱ C°	D D D	
		H S H }	E W	
		M }	G	
		J C & C°	G A W	
		O ✱ L	J W	
		S R & C°	L ✱ L	
		Skepsta	S ♂ B	
		U B }	S ✱ F	
		B & C° }	U × S	
		♛ }	W M	
		W A L L }	W ✱ S	

GEFLE.

1st.	2nd.	1st & 2nd Mixed.	3rd.	4th Quality.
P M	R × C	B B	B L	C × × B
R W ♛ S	R W × S	C ♛ B	C × B	D M
		C V B	C × × B	E ✱ B
		D M	D × A	E × × B
		E I B	D O M	+ M +
		E K B	E I I B	P
		G R A	E × B	S A G
		J ♛ P	H A	W
		K A B	H A B	✱ ✱ ✱
		K H	J P	
		K H B	N A S	
		S K B	W × S	

SODERHAM.

1st.	2nd.	1st & 2nd Mixed.	3rd.	4th Quality.
♛ }	M × T	C × D	B C	
E S B }	S T H	E S B	C	
J F S	V	G C & C°	G G	
M ♛ T		M A R M A	G G G	
W		O O O	M B	
		O W & C°	M M M	
			O W	
			O × W	
			S S T	

HUDIKSVALL, NORKOPING, SUNDSWALL, STOCKHOLM, LOJUNE, AND MO.

1st.	2nd.	1st & 2nd Mixed.	3rd.	4th Quality.
S ♛ B TUNA	S × B	CE FIIK F & C° 1 GE J ♛ F JGGG & C° MX OB & C° W ♛ R WIRA } MIXED } WWB	DDD F & C° 2 JEF K × T NW NX RAR RRR WW WIRA } TERTIA }	JEFO OX

RUSSIAN PORTS.

ULEABORG, ST. PETERSBURG, AND BJORNEBORG.

A } red } B FJF JIG NBI PB	CMB NBii PB2	BSSC B } US }	BC	

PRUSSIAN PORT.

DANTZIC.

Crown Deck.	Crown Brack Deck.
CCB } ♛ } EHEHEH ♛ ♛ } JCB } SKSKSK	CCB EH FGF JCBJCBJCB ♛ RJ SKSK

Deals from Russia and Finland are principally of 1st and 2nd qualities only, and usually, however, branded with the blow of a hammer and not stencilled like Swedish goods by red paint. Brands are at all times perplexing, as in some cases, Deals marked 2, 3, 4, 5 and even 6, do not denote quality, but simply the No. of yard from which they are taken. Goods from Canada are not generally branded, but

the different qualities of Pine Deals are seen by red marks on the sides thus,—i, ii, iii, denoting first, second and third qualities.

Hewn timbers are generally branded with the hammer at the ends, but the quality of Memel timber is given by marks with a scribe in the centre, i, ii, for bests and seconds. Dantzic timber is readily told from other kinds by a multiplicity of private marks in the centre.

Log timber of all kinds and Deals are now universally converted into scantling and boards by means of machinery, viz., reciprocating frame saws and circular saws. In London, a different system of charging sawing of deals is adopted to that in the provinces, viz., cuts are charged so much per dozen, the price varying with the length; *ripping* being called *flat-cuts* in the same way. We prefer however the country method, by which all cuts in the deal or log are charged for at per 100 feet super., and all rips or flat-cuts under 6 inches, are charged at per 100 feet lineal, and we herewith give the usual list of prices for this work, viz :—

					X cuts.
Oak . . .	4/0 per 100 ft. super.	1/6 ripping per 100 ft. run,			each 4d.
Mahogany .	5/6	,,	1/6	,,	,, 4d.
Memel . . .	2/6	,,	1/0	,,	,, $2\frac{1}{2}$
Swede & Yellow Pine .	2/3	,,	10d.	,,	,, $2\frac{1}{2}$
Pitch Pine .	3/9	,,	1/6	,,	,, 3d.
Deals . . .	1/9	,,	9d.	,,	,, $\frac{3}{4}$
Planing Deals	1/6	,,			
Chipping, do.	1/0	,,			

Matching, Rebating or Grooving for Hoop Iron, 3d. per 100 ft. super.

The prices of Deals vary according to their qualities, the current rate of freights and scarcity in the market. Our average present rate however would be as follows, viz :—

Spruce	£9	15	0	per standard.
1st quality, red	16	10	0	,,
2nd do.	13	10	0	,,
3rd do.	11	0	0	,,
Best Pine Deals (bright)	23	0	0	,,
Do. (floated)	22	0	0	,,
2nds Pine	15	0	0	,,

As a guide to those who are not thoroughly conversant with timber in standards, and prefer quotations by the foot run, we append a

scantling list we established some time ago, and which contains the chief sizes to be obtained from Deals, and in designing works of any kind, it is advisable to select scantlings of some of the sizes given, as we shall hereafter shew that if log timber is obliged to be used, the increased cost is considerable. (See pages 11 to 13.)

We also give the cost per square, that is, of 100 feet super, or 10 feet by 10 feet of boardings out of Deals, and their cost when planed and prepared ready for use in flooring. (See pages 14 and 15.)

With regard to log timber and its conversion, in arriving at the correct value of scantling cut from it, a number of things require to be taken into account. Having arrived at the cost price of timber as bought from the place of export, adding freight (always varying), and insurance, dues, &c., you arrive at the prices at which you are prepared to sell, bearing in mind that the value is increased or decreased in accordance with the average size or number of cube feet in each log, as generally large sized timber is more valuable than small sized. Then the lengths of the pieces to which it requires to be converted are taken into account; thus, if you wish pieces 8 feet long, and the logs mostly run 23 or 31 feet, the odd 7 feet is left on hand after the log is cut, and is not so valuable in this short length. The log may also be 12 by 12 inches, and the scantlings you require 6 by 8 inches, thus only cutting two pieces, and leaving a slab 12 by 4 inches on hand; this again is not so valuable, and increases the cost of the scantling. In addition to this there is the risk of the log turning out unsound. From a very lengthened experience in converting timber generally of all kinds we are able to give the table on page 16 as a guide, showing the value of different-sized sections of converted scantling at per cube foot, the timber from which it is cut being valued at its ordinary selling price in the log. It is assumed that an equal quantity of each of the sections of scantling are cut from each size of log mentioned at top of column, and the price given is the mean average cost. As, in a variety of cases, the slab on outside pieces need not be sawn off, we give two rates—first, with slabs one or two sides of the scantlings, and secondly, scantlings sawn all round. We have not mentioned sizes which may be readily got from deals, nor have we quoted for sizes which cannot be got from the kind of timber used.

PRICE LIST OF DEALS, BATTENS, BOARDS, LATHS, SCANTLINGS, AND PREPARED FLOOR BOARDS.

The Prices given are for the Goods Delivered Free into Broad or Narrow Gauge Trucks, Canal Boats, or to Carriers.

	No. of Section.	Size so called.	Size off the saw.	Price per foot run, in pence.					Weight per 100 feet run in lbs.	Size so called.
				A	B	C	D	E		
		in. in.	in. in.	d.	d.	d.	d.	d.		in. in.
FOREIGN SAWN DEALS, BATTENS, AND BOARDS	561	$1\frac{1}{4} \times 6$	$1\frac{1}{4} \times 6$		$1\frac{1}{8}$	$1\frac{1}{4}$			178	$6 \times 1\frac{1}{4}$
	562	$1\frac{1}{4} \times 7$	$1\frac{1}{4} \times 7$		$1\frac{1}{4}$	$1\frac{1}{2}$			208	$7 \times 1\frac{1}{4}$
	596	$1\frac{1}{2} \times 7$	$1\frac{1}{2} \times 7$		$1\frac{1}{2}$	$1\frac{3}{4}$			249	$7 \times 1\frac{1}{2}$
	623	2×9	2×9		$2\frac{1}{2}$	3			425	9×2
	636	$2\frac{1}{2} \times 7$	$2\frac{1}{2} \times 7$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{3}{4}$			415	$7 \times 2\frac{1}{2}$
	644	3×7	3×7	$2\frac{1}{4}$	$2\frac{3}{4}$	3	4		496	7×3
	645	3×8	3×8	$2\frac{1}{2}$					567	8×3
	646	3×9	3×9	$2\frac{7}{8}$	$3\frac{1}{2}$	$4\frac{1}{4}$	5	$6\frac{1}{2}$	642	$9 \times$
	647	3×11	3×11	$3\frac{1}{2}$	$4\frac{1}{4}$	5	6	$7\frac{1}{2}$	789	11×3
	651	4×9	4×9		5				850	9×4
	652	4×11	4×11		6				1039	11×4

	No. of Section.	Size so called.	Size off the saw.	Price per foot run, in pence. A	B	C	D	E	Weight per 100 feet run in lbs.	Size so called.
		in. in.	in. in.	d.	d.	d.	d.	d.		in. in.
SCANTLINGS	570	$1\frac{1}{2} \times 1\frac{1}{2}$	$1\frac{1}{2} \times 1\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$		1		54	$1\frac{1}{2} \times 1\frac{1}{2}$
	577	$1\frac{1}{2} \times 2$	$1\frac{1}{2} \times 2$		$\frac{3}{4}$				76	$2 \times 1\frac{1}{2}$
	587	$1\frac{1}{2} \times 3$	$1\frac{1}{2} \times 3$	$\frac{3}{4}$	1		$1\frac{1}{4}$		110	$3 \times 1\frac{1}{2}$
	590	$1\frac{1}{2} \times 3\frac{1}{2}$	$1\frac{1}{2} \times 3\frac{1}{2}$	$\frac{3}{4}$	1		$1\frac{1}{4}$		126	$3\frac{1}{2} \times 1\frac{1}{2}$
	592	$1\frac{1}{2} \times 4$	$1\frac{1}{2} \times 4$		$1\frac{1}{4}$				142	$4 \times 1\frac{1}{2}$
	594	$1\frac{1}{2} \times 4\frac{1}{2}$	$1\frac{1}{2} \times 4\frac{1}{8}$	1	$1\frac{1}{4}$		$1\frac{3}{4}$		162	$4\frac{1}{2} \times 1\frac{1}{2}$
	595	$1\frac{1}{2} \times 5\frac{1}{2}$	$1\frac{1}{2} \times 5\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	200	$5\frac{1}{2} \times 1\frac{1}{2}$
	600	$1\frac{3}{4}f \times 2$	$1\frac{3}{4} \times 2$		$\frac{3}{4}$	1			85	$2 \times 1\frac{3}{4}$
	605	$1\frac{3}{4}f \times 4$	$1\frac{3}{4} \times 3$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	130	$3 \times 1\frac{3}{4}$
	607	$1\frac{3}{4}f \times 4$	$1\frac{3}{4} \times 4$		$1\frac{1}{4}$				170	$4 \times 1\frac{3}{4}$
	609	2×2	$1\frac{7}{8} \times 2$		$\frac{3}{4}$	1			95	2×2
	613	$2 \times 2\frac{1}{2}$	$1\frac{7}{8} \times 2\frac{1}{2}$	$\frac{3}{4}$					122	$2\frac{1}{2} \times 2$
	616	2×3	$1\frac{7}{8} \times 3$		1	$1\frac{1}{4}$			142	3×2
	618	2×4	$1\frac{7}{8} \times 4$		$1\frac{1}{4}$	$1\frac{3}{4}$			189	4×2
	620	$2 \times 4\frac{1}{2}$	$2 \times 4\frac{1}{2}$		$1\frac{1}{2}$	$1\frac{3}{4}$			213	$4\frac{1}{2} \times 2$
	621	$2 \times 5\frac{1}{2}$	$1\frac{7}{8} \times 5\frac{1}{2}$		$1\frac{3}{4}$				262	$5\frac{1}{2} \times 2$
	633	$2\frac{1}{2} \times 3\frac{1}{2}$	$2\frac{1}{2} \times 3\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$			213	$3\frac{1}{2} \times 2\frac{1}{2}$
	634	$2\frac{1}{2} \times 4$	$2\frac{1}{2} \times 4$	$1\frac{1}{4}$					243	$4 \times 2\frac{1}{2}$
	639	3×3	3×3	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2		227	3×3
	640	$3 \times 3\frac{1}{2}$	$3 \times 3\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$		262	$3\frac{1}{2} \times 3$
	642	3×4	3×4		$1\frac{3}{4}$				284	4×3
	643	$3 \times 4\frac{1}{2}$	$3 \times 4\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$		320	$4\frac{1}{2} \times 3$
	644	$3 \times 5\frac{1}{2}$	$3 \times 5\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	4	394	$5\frac{1}{2} \times 3$
	650	$4 \times 4\frac{1}{2}$	$4 \times 4\frac{1}{8}$		$2\frac{1}{2}$				425	$4\frac{1}{2} \times 4$
	651	$4 \times 5\frac{1}{2}$	$4 \times 5\frac{1}{2}$		$2\frac{3}{4}$				524	$5\frac{1}{2} \times 4$

	No. of Section.	Size so called.	Size off the saw.	Price per 100 feet run, in pence.					Weight per 1000 feet run in lbs.	Size so called.
				A	B	C	D	E		
		in. in.	in. in.							in. in.
LATHS	495	1 × 3	$\frac{7}{8}$ × 3	3/5	4/2	4/11	5/10	6/9	723	3 × 1
	471	1 × $1\frac{1}{2}$	1 × $1\frac{7}{16}$	1/10	2/7	2/7	3/1	3/6	373	$1\frac{1}{2}$ × 1
	391	$\frac{3}{4}$ × 3	$\frac{11}{16}$ × 3	2/10	3/5	3/10	4/8	5/6	557	3 × $\frac{3}{4}$
	384	$\frac{3}{4}$ × $2\frac{1}{4}$	$\frac{11}{16}$ × $2\frac{1}{8}$	2/1	2/6	2/9	3/6	3/10	391	$2\frac{1}{4}$ × $\frac{3}{4}$
	377	$\frac{3}{4}$ × $1\frac{1}{2}$	$\frac{11}{16}$ × $1\frac{3}{8}$	1/4	1/7	1/11	2/4		267	$1\frac{1}{2}$ × $\frac{3}{4}$
	331	$\frac{5}{8}$ × 3	$\frac{9}{16}$ × 3	2/10	3/3	3/9	4/6	5/-	493	3 × $\frac{5}{8}$
	325	$\frac{5}{8}$ × 2	$\frac{9}{16}$ × 2		2/4	2/7			315	2 × $\frac{5}{8}$
	182	$\frac{1}{2}$ × $1\frac{1}{2}$	$\frac{3}{8}$f × $1\frac{7}{16}$	1/-	1/2	1/5	1/9	1/11	186	$1\frac{1}{2}$ × $\frac{1}{2}$
	162	$\frac{1}{2}$ × $1\frac{1}{8}$	$\frac{3}{8}$ × 1	10*d.*	11*d.*	1/1	1/2	1/5	130	$1\frac{1}{8}$ × $\frac{1}{2}$

NOTE.—The column headed—
A gives the price out of Spruce Deals
B " " of 2nd Red ditto
C gives the price out of Best Red or 2nd Yel. Pine Deals.
D " " Christiana ditto
E " " Best Yellow Pine ditto

f indicates size *full.*

Rates of carriage from various Railway Stations are—

For Scantlings and Boards..... per Ton
" Laths ..... "
" Prepared Flooring and Boards. "
} or a Dead Weight of say 65 Cube feet of Timber.

Generally all Goods are sent at "owner's risk," unless specially ordered otherwise.

	No. of Section.	Thickness so called.	Thickness off the saw.	PRICE PER SQUARE. A	B	C	D	E	Weight per Square.	Usual Widths.
FOREIGN SAWN PLANKINGS AND BOARDINGS.	26	1 inch	1 inch		12/9	16/-			284	7 in. only
	27	1¼ inch	1¼ inch		16/3	20/-			354	6, 7
	29	1½ inch	1½ inch		19/6	24/3			425	7
	30	2 inch	2 inch		24/-	30/-			567	9
	31	2½ inch	2½ inch	22/9	30/6	36/9			710	7
	32	3 inch	3 inch	27/6	36/9	45/6	54/6	66/6	853	7, 9, 11
	33	4 inch	4 inch		49/-				1134	9, 11
ENGLISH CUT BOARDINGS.	7	5/16 inch f	¼ inch f	4/7	5/7	6/7	7/8	9/-	92	7, 9, 11 in.
	10	⅜ inch	4/16 inch	5/-	6/6	7/2	8/5	9/9	102	7, 8, 9, 11
	12	7/16 inch	5/16 inch f	5/6	7/-	7/9	9/6	11/1	122	7, 8, 9, 11
	13	7/16 inch	⅜ inch		6/3	7/4			118	7, 8
	15, 14	½ inch	7/16 inch	6/1	7/7	8/10	11/7	12/3	142	7, 8, 9, 11
	16, 17, 19	⅝ inch	9/16 inch	6/11	8/10	10/9	12/7	14/6	180	6, 7, 8, 9, 11
	21, 22	¾ inch	¾ inch	8/8	10/5	12/8	15/2	17/3	213	7, 8, 9, 11
	24	13/16 inch	¾ inch	9/-	11/6	14/3			243	7, 8
	25	1 inch	15/16 inch	10/9	13/6	16/6	19/6	24/-	283	7, 9, 11
	27	1¼ inch	1¼ inch	12/6	16/4	19/9			353	7, 8
	29	1½ inch	1½ inch	15/-	19/6	23/6	29/3	33/3	425	7, 9, 11

NOTE.—The columns A, B, C, D, E, signify the different qualities as given on page 13.

				2nds White	Best White	2nds Red	Best Red			
PREPARED FLOORING.		1 × 7	$\frac{7}{8}$ × $6\frac{7}{8}$	11/10	12/8	12/1	14/10		284	Foreign Sawn and Planed.
		1 × 7	$\frac{7}{8}$ × $6\frac{7}{8}$	12/5	13/6	14/10	18/2		284	English do.
		$1\frac{1}{4}$ × 7	$1\frac{1}{8}$ × $6\frac{7}{8}$	14/2	15/5	18/-	21/5		353	Do.
		$1\frac{1}{2}$ × 7	$1\frac{1}{8}$ × $6\frac{7}{8}$	15/6	17/-	21/2	25/3		425	Do.

MATCHED, BEADED, AND WEATHER BOARDING.

Thickness so called ..	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.	$1\frac{3}{4}$ in.	2 in.
Matched, Beaded, and Planed one side, Spruce, at per square	..	11/7	13/-	14/1	16/6	18/10	21/6	24/-
do. 2nd quality, red do.	..	13/6	15/3	16/9	19/6	22/9	25/9	29/2
do. 1st do. do. do.	..	15/6	17/6	19/4	22/9	26/4	29/2	34/4
do. Planed both sides, Spruce do.	..	..	..	15/10	18/3	20/4	22/10	25/6
do. 2nd quality, red do.	..	..	..	18/6	21/-	24/6	27/2	30/7
do. 1st do. do. do.	..	..	..	21/-	24/6	27/10	30/7	35/9
Eassie's Wave Joint Boarding, Spruce do.	..	..	..	14/-	16/6	18/10	..	..
do. 2nd quality, red do.	..	..	14/4	16/9	19/6	22/9	..	..
do. 1st do. do. do.	..	..	16/9	19/-	22/9	26/4	..	..
Rebated Feather-edged Rough Boarding, Spruce	..	..	..	10/-	11/4	12/6	..	..
do. 2nd quality, red per sq.	10/-	12/-	.	15/1	..	..	..	..
do. 1st do. do. do.	11/7	14/2	..	17/4	..	..	..	..
do. wrought one side, Spruce do.	..	..	..	11/7	13/-	14/2	..	..
do. 2nd quality, red do.	11/9	13/6	..	16/9	..	..	..	..
do. 1st do. do. do.	13/4	15/6	..	19/-	..	..	..	..

	Swede 1/3 9 × 9 to 13 × 13.		Dantzic 1/5 12 × 12 to 16 + 16.		Memel, 1/7. 11 × 11 to 14 × 14		Pitch Pine, 1/7. 11 × 11 to 15 × 15.		Building Pine, 1/10. 12 × 12 to 14 × 14.		Board Pine, 2/3. 14 × 14 to 18 × 18.	
	Slab on one or two sides.	Sawn all round.	Slab on one or two sides.	Sawn all round.	Slab on one or two sides.	Sawn all round.	Slab on one or two sides.	Sawn all round.	Slab on one or two sides.	Sawn all round.	Slab on one or two sides.	Sawn all round.
4 × 12	1/9½	2/3	1/8½	2/1	1/11½	2/5	2/3	2/4	2/2½	2/9	2/10	3/2
4 × 16			1/7½								2/8	3/1
4½ × 6	1/9	2/2½	1/10	2/1	2/0½	2/4	2/2	2/6	2/4	2/9	2/10	3/1½
4½ × 7	1/10½	2/1½	1/11	2/1½	2/2	2/4½	2/4	2/6	2/7	2/9	2/10	3/2
4½ × 8	1/9½	2/1	1/11½	2/2	2/3½	2/5	2/4	2/6	2/8	2/9	2/10½	3/2
5 × 6	1/9½	2/3½	1/9½	2/2	2/	2/6	2/2	2/6½	2/4	2/11	2/11	3/2
5 × 7	1/10	2/2	1/10	2/2	2/1½	2/5	2/3	2/6½	2/5	2/11	2/11	3/2½
5 × 8	1/9½	2/1½	1/10	2/2	2/2½	2/4	2/3	2/6½	2/6	2/10½	2/11	3/2½
5 × 9	1/9	2/	1/10	2/1	2/1	2/4	2/3	2/6	2/5	2/10½	2/11½	3/2½
5 × 12	1/10	2/4	1/9½	2/0½	2/0½	2/4	2/3	2/5½	2/4	2/10½	2/11½	3/2
5 × 16			1/8½								2/9	3/1
6 × 6	2/	2/4½	1/9½	2/4½	2/2	2/11½	2/5½	2/9	2/3	2/10½	2/10½	3/4
6 × 8	1/11½	2/3	1/9	2/3½	2/2	2/9	2/4½	2/7	2/3½	2/9½	2/9	3/3
6 × 10	2/	2/3½	1/9½	2/2½	2/2	2/6	2/4	2/6	2/4½	2/11	2/11	3/3½
6 × 14			1/8½	2/4½	1/10		2/2	2/3	2/2½		2/9½	3/3
7 × 7	2/3	2/3½	1/10½	2/4½	2/2½	2/11	2/6	2/6½	2/6	3/7½	2/10½	3/5
7 × 8	2/0½	2/2½	1/10	2/4½	2/3	2/10	2/5½	2/6	2/6	3/7	2/10½	3/4
7 × 14			1/9	2/4	1/10		2/5	2/6	2/5½		2/10	3/2
8 × 8	1/11	2/1	1/11½	2/7	2/5½	2/9	2/6	2/10	2/11	3/3½	3/0	3/5½
8 × 10	1/11½	2/1½	1/10½	2/3	2/2½	2/6	2/5½	2/7	2/7½	2/11½	3/0½	3/5
8 × 14			1/8½	2/1	2/1		2/3½	2/5½	2/4		2/10½	3/2
9 × 6	2/0½	2/1½	1/11	2/2½	2/2½	2/7	2/4	2/6½	2/6	3/0½	3/	3/4
9 × 7	1/11½	2/1½	1/11	2/2½	2/2½	2/7	2/4	2/6½	2/6	3/0½	3/	3/4
9 × 8	1/9½	2/	1/11	2/2	2/2	2/6½	2/4	2/6	2/6	3/	3/1	3/4
9 × 12	2/1	2/2	1/11	2/1	2/1½	2/6	2/4	2/5½	2/5	3/	3/2	3/4
9 × 16			1/9								2/10	3/
10 × 10	1/10	2/4	1/11½	2/2	2/2	2/4	2/4½	2/6½	2/6½	2/9½	3/5	3/6½
10 × 14			1/9½	2/0½	2/0½		2/3	2/4	2/3½		3/1½	3/4
11 × 14			1/9½	2/	2/		2/1	2/4	2/3		3/1½	3/2½
12 × 12	2/	2/4	1/10	2/0½	2/1	2/2	2/2	2/3½	2/4½	2/6	3/0½	3/3
12 × 16			1/8½								2/10½	3/2
14 × 14			1/9½	1/11½	1/7		2/1	2/2			2/11½	3/1½
14 × 16			1/8								2/9½	3/0½

There can be nothing of greater consequence to those building than a proper understanding of the conversion of timber and the selection of such sized logs as will cut into scantling to the best advantage. Few builders can afford to have large quantities of waste and slabs thrown on their hands, and it will be better always to submit a list of the scantling, giving number, length, and size to any large saw mill proprietors for a price per cube foot of the converted scantling, sawn all round or with one or two slabs, as the case may be, as they have markets for the waste material. For general estimating purposes the above table will be found reliable.

CHAPTER II.

JOISTS, FLOORING, AND GIRDERS.

Single joisted, Double and Framed Floors, Scantlings of Joists, Wall Plates, Binders, Ceiling Joists and Girders. Flooring—Cost of Various Kinds, Value of Labour, Transverse Strength of Beams, Strength of Pillars, Posts, and Tensile Strength of Materials, with Examples.

AS we intend in this treatise to follow all the descriptions of work in their natural rotation, that is, as each portion would be required, supposing a building in course of erection, we come now to the question of joists and flooring. The timbers used in forming the floor of a room are called *naked flooring*; when the bearing between the walls runs from 15 to 16 feet, *simple joists* (see figs. 1 and 2), are used to

Fig. 1.

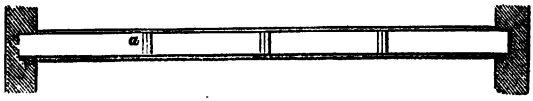
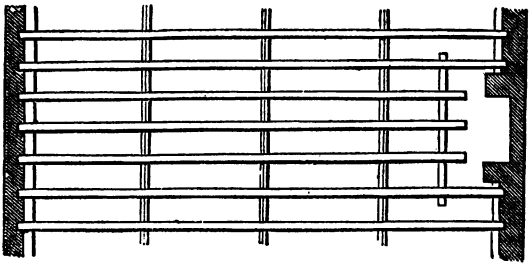


Fig. 2.



support the floor, and where there is a ceiling under, the *ceiling laths* are simply nailed to their bottom edge. A piece of timber called a *wall plate* (usually made the same thickness as a brick, so as not to

interfere with the proper coursing of the brickwork is used at the ends of the joists to equalise the bearing on the wall. This is the simplest possible floor, and is called the *single joisted floor*. The joists are usually 12 inches apart or 16 inch centres. Their scantling varies according to the span of the room and the load it has to carry. The following table will give the usual sizes of joists for ordinary dwelling houses for every length of 5 feet, the joists being taken as 12 inches apart and also the usual sizes of wall plates, the scantlings being in preference chosen from deals as being most easily procured. The weight to be sustained by floors are for—

	Per ft. super.
Dwelling Houses	$1\frac{1}{4}$ cwt.
Public Rooms, Lecture Rooms ..	$1\frac{1}{2}$,,
Warehouses, Factories, &c ..	$2\frac{1}{2}$,,

SCANTLING OF JOISTS.

Length of Bearing.				
5	$4\frac{1}{2} \times 2$	$4 \times 2\frac{1}{2}$	$3\frac{1}{2} \times 3$
10	$9 \times 1\frac{1}{2}$	$7 \times 2\frac{1}{2}$	
15	$11 \times 1\frac{1}{2}$	10×2	$9 \times 2\frac{1}{2}$
20	11×3	10×4	
25	12×3	11×4	

SCANTLING OF WALL PLATES.

Joists, up to 10 feet	3×3
,, From 10 to 20	$4\frac{1}{2} \times 3$
,, ,, 20 to 30	7×3

When the bearing exceeds 10 feet it is usual to place *herring bone strutting*, consisting of pieces of wood about $3 \times 1\frac{1}{2}$ nailed in a line and between and across the joists from the top of one to the bottom of the next. (See fig. 3.) When joists, owing to fireplaces, staircases, &c., cannot have a bearing on the wall, a trimmer is used, its thickness being increased $\frac{1}{8}$ of an inch for each joist carried by it, but the same depth as the joists. The joists to which the trimmer is fixed are also made thicker to allow for their being weakened by the tenon of the trimmer. (See fig. 2.) To prevent the passage of sound, *pugging* is often adopted in the best style of houses,

Fig. 3.

which consists of thin boards in short lengths, making as it were a second floor laid between the joists and resting on fillets nailed to the lower edges of the joists covered with about 3 inches in depth of lime, mortar, earth, or light ashes. (See fig. 4.) The weight of common single joisted floors may be taken as 740 lbs. per square.

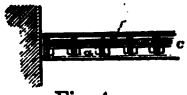


Fig. 4.

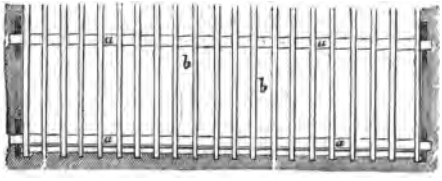
On ground floors of buildings sleeper walls or brick piers may be built, thus reducing the length of the bearing and so saving scantling

Fig. 5.

in the joists. (See fig. 5.) The weight per square of this flooring may be taken as 300 lbs. per square.

A *double floor* consists of three tiers of joists where ceilings occur, viz., binding joists, bridging joists, and ceiling joists. The binders (see figs. 6 and 7) have their ends resting on the walls and are usually

Fig. 6.



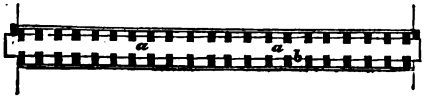


Fig. 7.

6 feet to 10 feet apart. The bridging joists are notched on the top to which the floor is nailed and the ceiling joists carry the lath and plaster of the ceiling. Proper scantlings for binders are given in the table below, their distance apart being taken as 6 feet. The weight of double floor framing on an average is 990 lbs. per square.

Length of Bearings. Ft.	In.				
5	0	..	..	..	7 × 3 or 9 × 2
7	6	..	..	..	9 × 3
10	0	..	..	..	9 × 4 or 11 × 3
12	6	..	..	..	11 × 4
15	0	..	..	..	12 × 4
20	0	..	..	..	13 × 6½
25	0	..	..	..	15 × 7½

Ceiling joists should never have long bearings, as their tendency to warp cracks the ceilings. The following table gives their scantlings when 12 inches apart.

Length of Bearings. Ft.	In.			
4	0	..	..	2½ × 1½ or 2 × 2
5	0	..	..	2½ × 2
6	0	...	..	3 × 2
7	0	...	..	3½ × 2 or 3 × 2¼
8	0	..	..	4 × 2 or 3 × 2½
9	0	..	..	4½ × 2 or 4½ × 2½ or 4 × 3
10	0	..	..	4½ × 2½ or 4½ × 3
12	0	..	..	5 × 3
14	0	..	..	6 × 3

FRAMED FLOORS have the binders framed into baulks of timber called *girders*, which last rest upon walls or piers. (See figs. 8 and 9.) When baulks of large timber are used as girders, they should be

Fig. 8.

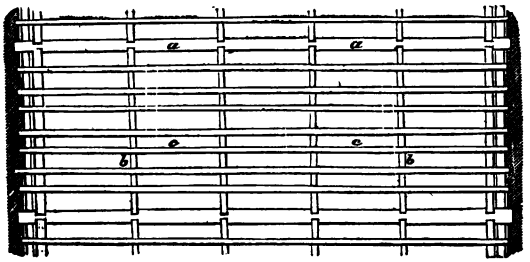


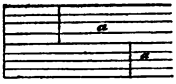
Fig. 9.

sawn down the centre and reversed, and the two parts bolted together to prevent twisting: besides testing the quality of the timber, an additional strength can also be gained by putting in a plate of iron, the full depth of joist, usually 1-20th of the width of baulk. This is termed a flitch girder. The weight of a framed floor is, on an average, 1,288 lbs. per square. For girders 10 feet apart the following table gives the several sizes, viz.:

Length of Bearing. Ft.	In.								
10	0	..	..	..	11 × $5\frac{1}{2}$	or	12 × 4
15	0	..	..	..	13 × $6\frac{1}{2}$	or	11 × 11
20	0	..	..	..	15 × $7\frac{1}{2}$	or	13 × 13
25	0	..	..	..	17 × $8\frac{1}{2}$	or	14 × 14
30	0	..	..	..	20 × 10		

It may be useful, as a guide, to state the comparative cost of these four different kinds of joisting. Taking, therefore, a floor single joisted with floor and ceiling-joist fixing included, as being equal to 100, the comparative cost of a ground floor, as shewn in Fig. 5, will be 58, to which the cost of piers or sleeper wall should be added. Double floor, as shewn in Figs. 6 and 7, will be 141, and a framed floor, as Figs. 8 and 9, would be 170.

Floor boards vary in thickness, and are kept in stock ready planed, and can be procured $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ inches thick; their actual thickness is really $\frac{1}{8}$th inch less than this, owing to the loss by saw and plane; they are generally $6\frac{7}{8}$ wide, but can be prepared $4\frac{1}{4}$ or $5\frac{1}{4}$ wide, and many architects prefer it laid in these narrow widths. They should be thoroughly seasoned, as they readily shrink; and a curious fact is, that no matter how long a floor has been laid, should it be taken up and reshot on the edges, it will again shrink. The floor boards are generally laid *folding;* that is, four are placed together and forced downwards between two or more already nailed down, in which case, the edges will be plain as at *a* in Fig. 10, or straight joint when laid as in Fig. 11, in which latter case the heading joints are splayed or tongued, as shown at *b*, *d*, *g*, and *h*. Their edges may be ploughed and tongued, as shewn at *b*, or rebated as at *c*, or the tongue may be either of a loose strip of wood or hoop iron, as

Fig. 10. 

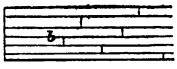
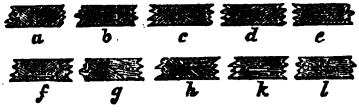


Fig. 11.



at *d*, *e*, or as we ourselves prefer it, the tongue may rest on the joists, as at *f*, the boards being brought close together by means of the flooring cramp.

The following Table gives the comparative cost of floor boards laid in Spruce, common and best Red, per square of 100 feet super.

Weight in lbs. per sq.	Thickness of Floor.	Cost planed Boards, ready for laying.	Cost of Nails.	Cost of Labour.	Remarks.	Total cost per Square.
			Spruce, at £9 per Standard.			
		s. d.	s. d.	s. d.		
213	$\frac{3}{4}$	9 10	0 3	2 6		0 12 7
283	1	12 3	0 4	2 9	7 widths	0 15 4
425	$1\frac{1}{2}$	17 0	0 10	3 8		1 1 6
853	3	29 6	1 6	6 6	9 widths	1 17 6
			2nd Red, at £13 per Standard.			
213	$\frac{3}{4}$	11 10	0 3	2 6		0 14 7
248	$\frac{7}{8}$	13 0	0 4	2 8		0 16 0
283	1	15 3	0 4	2 9		0 18 4
354	$1\frac{1}{4}$	18 3	0 8	3 3	7 widths	1 2 2
425	$1\frac{1}{2}$	21 6	0 10	3 8		1 6 0
567	2	27 10	1 0	4 8		1 13 6
710	$2\frac{1}{2}$	35 0	1 4	5 6		2 1 10
853	3	41 6	1 6	6 6	9 widths	2 9 6
			Best Red flooring, £17 per Standard.			
213	$\frac{3}{4}$	14 10	0 3	2 6		0 17 7
248	$\frac{7}{8}$	16 6	0 4	2 9		0 19 7
283	1	19 3	0 4	2 9	7 widths	1 2 4
354	$1\frac{1}{4}$	23 6	0 8	3 3		1 7 5
425	$1\frac{1}{2}$	27 6	0 10	3 9		1 12 1

As the cost of labour varies in different localities, we append the constants for labour in framing floors per cube foot.

Days of Carpenter.

	Ground joists, Bond timbers, Plates rough.	Rafters, Purlins, Ceiling joists, &c.	Rough frames, naked floors, &c.	Trusses.
16 sqr. in section and under	·04	·06	·1	·12
6 ,, ,, .	·04	·05	·07	·1
81 ,, ,, .	.035	·046	·06	·07
Over the above . . .	·03	·04	·05	·06

Laying floorboards, machine planed and edged per square :

	Broken joints.	Laid folding, and tongued, and splayed headings.
$\frac{3}{4}$	·45	·54
1	·50	·60
$1\frac{1}{4}$	·59	·71
$1\frac{1}{2}$	·67	·80
2	·85	1·02
$2\frac{1}{2}$	·99	1·18
3	1·15	1·38

As a guide to the sections that should be used in lintels, beams, joists, &c., we append the formulas for calculation. Taking, first of all, a beam supported at both ends, and loaded in the middle, as in Fig. 22.

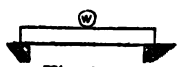


Fig. 22.

The formula in this case is $W = \frac{2\,S\,b\,d^2}{3\,l}$ (1)

W breaking weight in lbs.

S constant determined by experiment, a list of which is given in the table (page 25) for different materials.

b breadth in inches.

d depth in inches.

l length in inches.

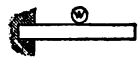
TABLE OF MECHANICAL PROPERTIES OF THE MATERIALS OF CONSTRUCTION.

	Weight of a cubic foot in lbs.	S value of the co-efficient of absolute transverse strength.	Value of a resistance to crushing per sq. inch in lbs.	Tenacity per square inch in lbs
	1	2	3	4
Ash or Beech	47—53	12,156	9,000	14,700
Box (dry)	60		10,300	19,800
Brass (cast)	525	18,000	10,300	18,000
Bricks	130		560—800	280
Brickwork	112	280—300		
Chestnut	41	10,660		11,900
Clay	119			
Coal	77—100			
Copper (cast)	549	19,000		19,000
Deals (red)	36—43	9,372	6,586	
,, (spruce)	21	9,900	6,293	
Earth (rammed) ..	99			
Elm	36	6,690	10,300	14.200
Fir (Riga)	47	6,648	6,000	12,000
Glass (plate)	153	9,400		9,400
Gold	1203			
Gravel..	120			
Granite	165			
Iron (wrought)	481	42,000	40,000	51,000
,, (cast solid) ..		39,000	115,000	20,000
Ivory	114			
Lance wood	63	17,350		23,000
Larch	32	5,118	5,570	9,500
Lead	712	3,300		3,300
Mahogany S.	50	11,500	8,200	19,000
Marble	164		6,060	
Mercury	848			
Marl	118			
Mortar	107	50		50
Oak E.	58	10,032	10,000	13,300
,, (Dantzic)	47	8,742	7,700	
,, (Canadian)	54	10,596		
Pine (Pitch)	41	9,792	6,790	7,800
,, (Red)	48	8,046		7,800
,, (American yellow)	28	6,612	5,400	
Poplar	23			6,016
Sand (river)	117			
Silver	644			
Slate	180	9,600		12,000
Steel	486	100,000		100,000
Stone	120—170	1100—2360	6,000	
Teak	41	14,772	12,000	12,460
Tin (cast)	455	4,600		4,600
Water	62			
Walnut	41		7,227	8,460
Zinc	439	7,000		7,000

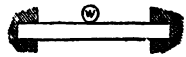
Factor of safety when load is fixed, is $\frac{W}{5}$

" when a moving load is $\frac{W}{7}$

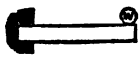
(*a*) If fixed at one end and loaded in middle, take $1\frac{1}{4}$ W.



(*b*) If the beam is fixed at both ends and loaded in middle, take $1\frac{1}{2}$ W.

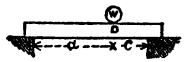


(*c*) If fixed at one end and loaded at the other, take $\frac{1}{4}$ W.



(*d*) Where loaded all over, take 2 W.

(*e*) When the load is applied to any other point, as at D, the formula (1) becomes $W = \frac{S\,b\,d^2\,l}{6\,a\,c}$



(*f*) When loaded in the middle, in which the span is taken in inches as before, the readiest formula to find the breadth, when the depth, length, and breaking weight is given is

$$b = \frac{3\,l\,W}{2\,d^2\,S} \qquad (2)$$

or if the beam is square, $b = d = \sqrt[3]{\frac{3\,l\,W}{2\,S}}$ (3)

What breadth should a Riga Fir beam be that is 12 *inches deep, to carry a wall* 10 *feet high of* 14 *inch brickwork; the clear span being* 12 *feet?*

Here the weight to be carried is 12 feet $\times$ 10 feet $\times$ 1 foot 2 inches = 140 feet cube at 112 lbs. = 15,680 lbs., equal to 7,840 lbs. if loaded all over; which again multiplied by the factor of safety, 5 = 39,200 lbs.; then formula (2)

$b = \frac{3\,l\,W}{2\,d^2\,S}$ becomes $b = \frac{39{\cdot}200}{4{,}432} = 8{\cdot}8$ inches nearly.

Example: *What is the safe load distributed all over for a piece of Riga Fir,* 12 *inches deep and* 6 *inches wide, placed over opening* 12 *feet in clear, and built in at each end?*

Then by formula (1) $W\,\frac{2}{3}\,S\,\frac{b\,d^2}{l}$ becomes W = 2 $\times$ 6,648 $\times$ 2 = 26,592 lbs. dividing by the factor of safety, 5,318 = safe load in

middle, and 10,636 lbs. distributed all over; it is built in at both ends, however, hence $\frac{10,636 \times 3}{2} = 15,954$ lbs. safe load.

While we are on the subject of strains, and to avoid recurring to it again, we will now, having considered the transverse strains or the resistance of materials to being broken across; take into account their tensile and crushing forces, and first as to its resistance to crushing. When materials are subject to a compressing force in the direction of their length, as in columns, struts, &c., they will either yield by bending, or by the crushing of the fibres, or by both together. This depends on its length as compared by its diameter.

If its length equals 30 times its diameter, it will break by bending.
If „ less than 25 times „ „ both by bending and crushing.
If „ „ 10 „ „ „ by crushing only.

The best formula for bending only, or when the pillar is more than 30 times its diameter in length is

$$W = 3 \frac{a\, d^4}{l^2} \qquad (4)$$

in which W equals breaking weight of very long columns in lbs.
„ a = constant giving in table.
„ d = diameter of pillar in inches.
„ l = length in feet.
„ factor of safety $= \frac{W}{10}$

When a pillar is more than 10, and less than 25 times its diameter in length, the formula becomes

$$W^1 = \frac{W\, C\, a}{W + \frac{3}{4}\, C\, a} \qquad (5)$$

in which C is the area of column, and W^1 the breaking weight of the column.

When under 10 feet the area of the support is simply multiplied by its resisting powers to crushing.

Example: *What weight will a piece of Riga Fir support safely if 4 inches square and 3 feet long?*

$4 \times 4 \times 6,000 = 96,000$ lbs. factor of safety $\frac{W}{10}$ therefore 9,600 lbs. is the safe load. If the piece was round, say 4 inches diameter, then $9,600 \times 7{\cdot}854 = 7,539$ lbs. or safe load.

Example: *What weight will the same piece carry if* 10 *feet long and* 4 *inches diameter?*

In this case take formula 4.

$$W = \frac{3\,a\,d^4}{l^3} = \frac{3 \times 6{,}000 \times 256}{100} = 46{,}080,$$ therefore safe load = 4,608 lbs.

Example: *What weight will the same piece carry if* 7 *feet long?*

In this case take formula 5.

$$W^1 = \frac{W\,C\,a}{W + \frac{3}{4}\,C\,a}$$

$$W = \frac{3\,a\,d^4}{l^3} = \frac{3 \times 6{,}000 \times 256}{49} = 94{,}041.$$

$$C\,a = 4 \times 4 \times 6{,}000 = 96{,}000.$$

therefore $W^1 = \frac{94{,}041 \times 96{,}000}{96{,}000 + 72{,}000} = 54{,}372$, therefore safe load = 5,437 lbs.

As the strength of cohesion must be proportional to the number of fibres in the wood or its area, it follows that its tenacity, or the weight which will tear it asunder lengthways will be found by multiplying the number of square inches in its section by the tensile strength given in column 4 the table-factor of safety being one-fourth.

Example: *What force will a piece of Larch take to pull asunder when its section is* 4 × 4?

4 × 4 × 9,500 = 152,000 lbs., which divided by 4, gives 38,000 safe tensile strain.

CHAPTER III.

ROOFS AND ROOFING MATERIALS.

Carpentry of Roofs of Various Kinds for Dwelling-houses, Temporary Buildings, &c., Weight of Coverings to Roofs, Strains on Same, Details and Comparative Cost of Slate, Tiles, Felt, Zinc, and Iron Coverings to Roofs.

ROOFS are classed according to their form—they are simply sloping surfaces at varying angles for the purpose of throwing off rapidly rain or snow from the building they cover. The slope given to roofs should vary only with the materials used in the covering unless architectural effect is required. The following are good slopes :—

	Height of Roof in parts of the span.
Lead	1-40th.
Galvanised Iron Zinc	1-5th.
Common Slates	1-4th.
Stone, Slate, and Plain Tiles	2-7ths.
Pantiles	2-9ths.
Thatch, Felt, and Wood	1-3rd to half.

The amount of annual rainfall in England averages 35 inches, in India 90 inches.

Carpentry in roofs are the timbers placed to receive the slates, &c. The simplest style is a *lean to* or shed roof (see Fig. 27) in which rafters are placed on wall plates, one being higher than the other, thus sloping to the lower wall. A common modification of this roof is shown in fig. 28, in which the feet of the rafters rest upon a framed gutter, carried by a horizontal beam stretching from wall to wall. It is a cheap roof for rows of houses, and is common in London. *Span roofs* in narrow buildings up to 20 feet or so (see Fig. 29) are composed of the same kind of rafters, joined at the apex to a ridge piece, and tied by means of *collars* to prevent their sagging or spreading. A *hip roof* is one whose ends rise direct from the wall,

Fig. 27.

and the angles made by the slopes meeting are called the *hips*; the short rafters necessitated by these angles are called *jack rafters*, a

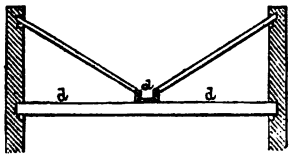


Fig. 28.

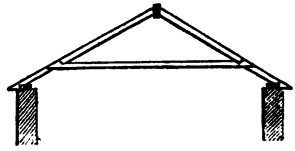


Fig. 29.

valley is the internal hollow angle made by the two planes of a roof. When boards are nailed on this angle to form gutters they are called *valley boards* and receive the lead or zinc. When the roof however becomes wider framing must be used. Trussed frames of carpentry thus used are called *principals*, and are distributed transversely at equal distances in the length of the building, such distances being made suitable to the strength of the purlins. These principals are of three or more kinds, mostly requiring tie-beams, the simplest being the *king-post roof* (see Fig. 30). The king-post is in this case introduced

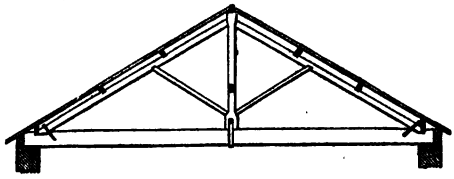


Fig. 30.

between the head of the principal rafters and the centre of the tie-beam. Into this post the head of the rafters are shouldered, thus holding up the post, which in its turn prevents the tie-beam from bending by means of a strap which passes under it; the feet of the main rafters being tied to the tie-beam prevents the roof from having any outward thrust on the wall. When two upright pieces are introduced to hold up the tie-beam the roof becomes a *queen-post* (see Fig. 31), and the horizontal piece between their heads, the straining beam. In both of these last roofs struts are inserted from the foot of the king and queen posts to the centre of main rafters, and in the

latter their thrust is counteracted by another straining piece placed on the top of the tie beam. The covering of the roof is sustained between

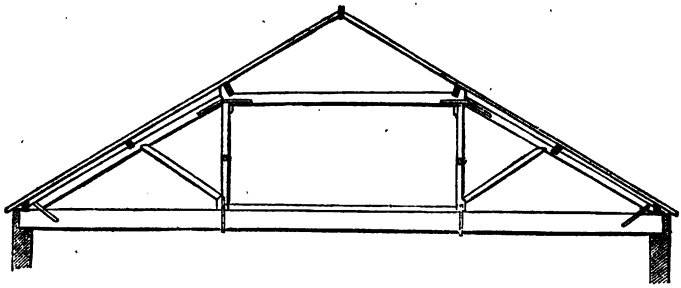


Fig. 31.

the principals by means of longitudinal beams called purlins, which again carry common rafters about 12 inches apart, on which the slate laths and slates are laid. For some purposes roofs are better close boarded before they are slated, in which case the boarding is laid on the common rafters. This is always done when the roof is covered with lead—in which case rolls of wood are placed from ridge to eaves every 3 feet or so, and a rounded roll on the ridge is spiked the whole length of the building, called a ridge roll, over which the lead is dressed. When there is a parapet wall at the eaves a gutter is formed of horizontal pieces called bearers, fastened to the feet of the rafters, on which gutter boards are placed to receive the lead. Fig. 32 shows a modification of the king-post roof, in which a wrought iron tie rod takes the place of the king post, and a casting through which the rod is taken secures the top of the principal backs.

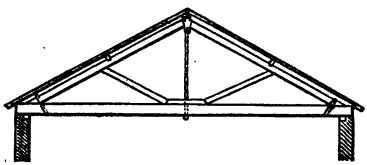


Fig. 32.

The lower straining beam is introduced as in a queen post roof. This is a good roof for sheds or workshops. Often, to produce architectural effect, or to economise space, a curb or Mansard roof is erected, as shown in Fig. 33. Here the rafters are in two separate lengths and form an external angle. It may be made of simple rafters, but usually it is a framed principal, as shewn. In this case it is a king

post roof supported and strutted by two side queen-posts and struts, the tie beam forming one of the supports of the floor. *Collar roofs*

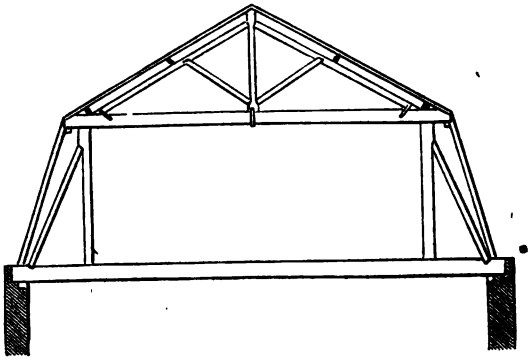


Fig. 33.

are frequently used in Gothic buildings, as churches, &c., and in Fig. 34 we show the simplest. The collar is placed high up, and with the

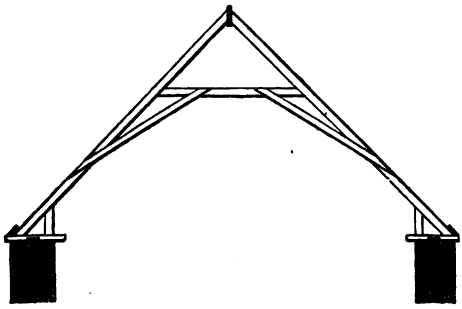


Fig. 34.

braces are tenoned at each end and fastened with oak pins. The foot of the rafter is fastened into a horizontal wall piece the full width of the wall, and a vertical strut is framed into each and pinned as before. There is thus little outward thrust. Some of the oldest Gothic roofs are found built as in Fig. 35. In this kind of roof the tie beam has a space cut clear away from its centre, and the remaining portion is called a hammer beam (hence its name, *hammer beam roof*). To prevent the outward thrust a strut is framed from its inner end to

a vertical piece resting on a corbel and against the wall. In this particular roof a king-post rests on the collar, and the usual vertical tie is

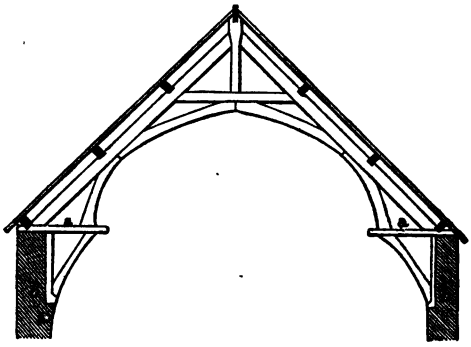


Fig. 35.

replaced by curved struts. The famed roof over Westminster Hall is of this type. Buttresses are necessary to prevent the outward thrust in large spans, or the wall must be of unusual strength. Fig. 36 is a

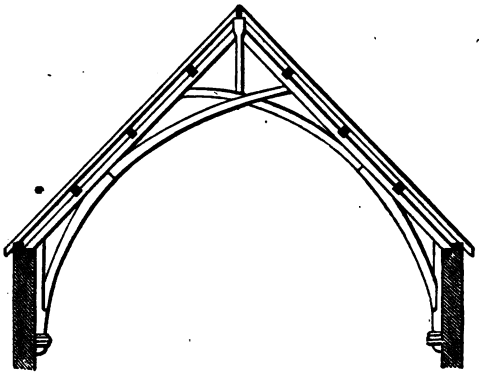


Fig. 36.

common church roof, and a very graceful one, the curved ribs are struts and ties combined; it is generally adopted where the building has stout stone walls. Sheds of wide span may be covered very

economically by the simple roof shown in Fig. 37. The thrust on the

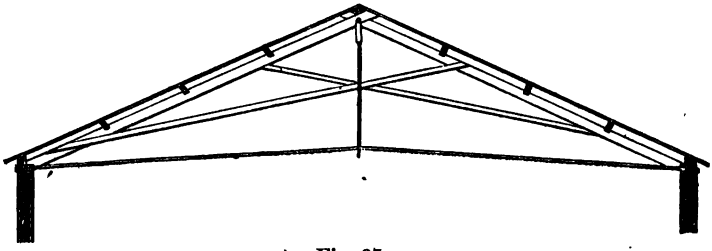


Fig. 37.

side walls is taken entirely by the tie rod passing through the wall plate. It is usually covered with light materials, as corrugated iron, zinc, or boards and felt. Figs. 38 and 39 are also roofs to be covered

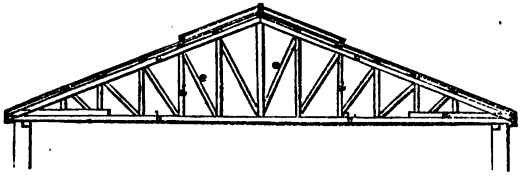


Fig. 38.

with light material, and as the latter, bow and girder roof is now extensively used, we append instructions for its erection, for which we are indebted to Messrs. Ellis & Co., of Liverpool. This roof is a seg-

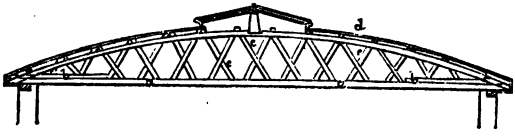


Fig. 39.

ment of a circle—of which the rise should be about one-tenth of the span—and consists of a string or tie made of two pieces of best spruce or pine, and a bow of two pieces of best pine, as free from flaws as possible.

The dimensions of these vary to suit the span, as per following table :—

Span in feet.	Bow.	String.	Web.	
			Ft. in.	
20	2 × 1	$2\frac{1}{2}$ × 1	4 0 × 5 × 1	Purlins are always 3 × 2, usually made of two pieces, 3 × 1, nailed together. Sheeting always $\frac{1}{2}$ in. Diagonal bracing, 3 × $\frac{3}{4}$.
30	2 × 1	$3\frac{3}{4}$ × 1	6 0 × $7\frac{1}{2}$ × 1	
40	2 × $1\frac{1}{4}$	5 × $1\frac{1}{4}$	8 0 × 10 × 1	
50	$2\frac{1}{4}$ × $1\frac{1}{4}$	$6\frac{1}{4}$ × $1\frac{1}{4}$	10 0 × $12\frac{1}{2}$ × 1	
60	$2\frac{1}{2}$ × $1\frac{1}{2}$	$7\frac{1}{2}$ × $1\frac{1}{2}$	12 0 × 15 × 1	

The diagonal bracing interposed between string and bow are well spiked together at all junctions and crossings with wrought nails, and their ends project so as to abut against the purlins, which latter are spaced about two feet apart on the girders. A solid web of timber, equal in length to one-fifth of the span is fitted between the strings at each end, so as to give additional strength in those places. The sheeting is $\frac{1}{2}$-inch thick (5 out of a 3-inch plank), in long lengths and from 9 to 15 inches broad, with the heading joints properly broken on the purlins, to which they must be well nailed. The two pieces of pine forming the bow are bent gradually to the shape, the girders are spaced 8 to 10 feet apart and are erected on a substantial wall plate, to which, on each side of the girder, a good stout wedge is spiked, and the girder is further secured by means of strong iron dogs 3 or 4 feet long, which attach it firmly to the wall. The felt must be brought right over the edge of the sheeting and turned in under, otherwise the roof will have the appearance of leaking, through the water

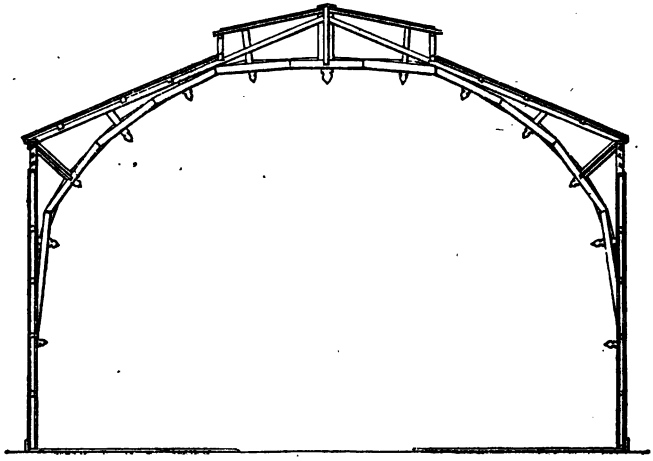


Fig. 40.

dropping off the roof being drawn up the boards by capillary attraction. Felt the roof as per instructions given in page 45.

Fig. 40 is the roof so well known in connection with the machinery annexe of the 1872 Exhibition, designed by the late Captain Fowke (it is also covered with a light material), the framing is made of 1½ and 1 inch boards, placed edgeways in short segments, the joints breaking with each other and well spiked. The principal rafters and uprights are in one length, and the latter strengthened by a piece of scantling nailed on each side. It can be very expeditiously erected, and a very large annexe of this kind, at the Oporto Exhibition, was framed and shipped from this country under the superintendence of Mr. Shields, C.E., in little more than a week. For drill halls, gymnasiums, riding schools, &c., the framed roof, similar to that shown in Fig. 41, is very appropriate. The principals are placed 20

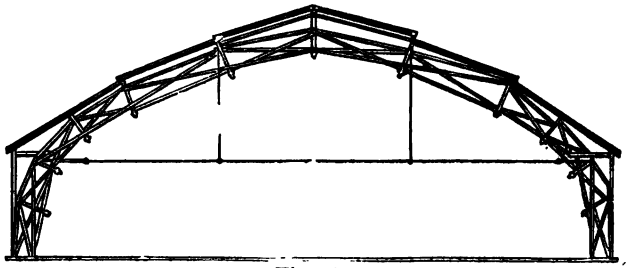


Fig. 41.

or more feet apart as the depth of the bracing allows of the purlins also being trussed. Buildings of this kind may be made from 100 to 150 feet span, and, with the exception of a few of the longest roof ties, may be composed entirely of deals.

We give here the comparative weight per square of the different materials forming the outside covering only, as a guide in estimating the strength required, viz.—

	Weight per Square.
Plain Tiles	15 cwts.
Pan Tiles	8 ,,
Zinc, 18 gauge	1½ ,,
Galvanised Corrugated Iron, 18 gauge ..	2½ ,,
¾ in. Boarding and Felt	3 ,,
Do. and 5 lb. Lead	7¼ ,,
Slates on Lath, average	7 ,,

In addition to this, there is the weight of the purlins, roof, principals, &c., which may be taken in wood or iron as ranging from 5 to 6 cwt. per square; and the accidental load, such as the weight of snow and wind pressure, may be estimated safely in this country at 30 cwt. per square. Large roofs are usually tested first with 40 lbs. per square foot, uniformly distributed over the whole roof, and next with a similar load on half the roof only. We may thus safely calculate the strains on roofs covered with tiles at 50 cwt.; zinc, felt, or corrugated iron at 38 cwt.; and lead and slates at 42 cwt. per square measured as space covered; and with the object of facilitating the calculation of these strains in cases mostly occurring in practice, we have given at the end of this work diagrams for different roof framings, in which the span and weight of the entire principal is represented by 1, and the figures indicate the strains which result. The actual strains are readily found by multiplying the span of the roof by the width between two principals in feet, and the product by the weight per square foot of the loaded structure; the result multiplied by the diagram numbers, gives the strain on each part in terms of the same weight. The tensile strains are shewn in the thin lines, and the compressive in the thicker ones.

ROOF COVERINGS.

Slate is largely used for covering buildings, being a natural material which splits readily into thin slabs, and is much lighter than tiles. There are various qualities—Bangor, blue or red being the best produced; those from Carnarvon the next best, and a good substitate for Bangor; Port Madoc also sends out a good slate; and the Festiniog also, the last named being cheap in the larger sizes. The Welsh slates are made into a great variety of sizes, and laid as in Fig. 42, which represents 3 courses of slates in which the distance from *a* to *b* is the lap, and from *b* to *c* the gauge. The gauge is, therefore, the half length of the slate less half the lap. They are sometimes laid on close boarding nailed to the rafters, in which case it is usual to

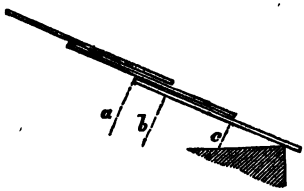


Fig. 42.

put a layer of sheathing felt on the boarding before laying the slates, but oftener on battens or slate lath, as in Fig. 43, placed at a distance

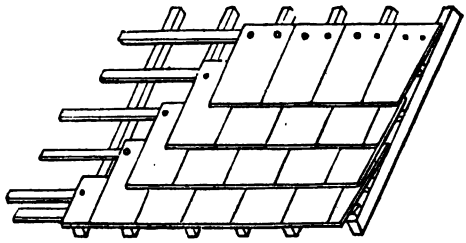


Fig. 43.

apart equal to the gauge to be given to the slates. The slates are fastened by copper or zinc nails, two to each slate, except in the small sizes, which have only one; these nails pass through holes punched near the centre and top of the slates. It is measured by the square of 100 feet super, 12 inches extra being allowed for eaves, hips and valleys, and irregular angles. Circular slating being one-third extra. The following is a Table of constants of labour for preparing and laying slates, quantity of lath, weight of lath and slate nails per square :—

Size of slates.	Feet run of lath.	Weight of lath nails in lbs.	Weight of nails in lbs.	Constant to be multiplied by the rate of wages for a slater and labourer per day, preparing and laying.
24 × 14	112	$\frac{3}{4}$	$1\frac{1}{2}$	·50
24 × 12	112	$\frac{3}{4}$	$1\frac{3}{4}$	·50
22 × 12	124	$\frac{7}{8}$	2	·53
20 × 12	135	1	2	·54
20 × 10	137	1	2	·55
18 × 10	155	$1\frac{1}{8}$	$2\frac{1}{2}$	·58
16 × 10	179	$1\frac{1}{4}$	$2\frac{1}{2}$	·59
16 × 8	178	$1\frac{1}{4}$	$2\frac{1}{2}$	·60
14 × 8	208	$1\frac{3}{8}$	3	·63
13 × 7	234	$1\frac{1}{2}$	$3\frac{1}{2}$	·66

The following table gives some of their various sizes, weight, &c. —

		PENRHYN or BANGOR. Blue or Red.				PORT MADOC and TYN-Y-OG.				No. of Slates per sqr. 2½ lap.
		1st quality.		2nd quality.		1st quality.		2nd quality.		
		Weight.	Price.	Weight.	Price.	Weight.	Price.	Weight.	Price.	
		cwts.		cwts.		cwts.		cwts.		
Princesses . .	24 × 14	55½	260/-			55½	270/-	64	228/-	96
Duchesses . .	24 × 12	48	236/-	65	197/-	48	233/-	55½	212/-	112
Marchionesses . .	22 × 12	44	202/-	55½	166/-	44	198/-	52	178/-	124
,, . .	22 × 11					40½	185/-	48	158/-	133
Countesses . .	20 × 10	32	167/-	42½	132/-	32	165/-	40	140/-	164
Viscountesses . .	18 × 10	30	133/-	37½	102/-	29	130/-	36	105/-	186
,, . .	18 × 9					25	105/-	32	98/-	210
Ladies . . .	16 × 10	25	103/-	34	89/-	24	100/-	30	94/-	214
,, . . .	16 × 9					22	90/-	26	73/-	238
,, . . .	16½ × 8½					20	83/-	25	68/-	240
,, . . .	16 × 8	20	80/-	26½	60/-	19	79/-	24	66/-	266
,, . . .	14 × 12	18½	86/-	36	69/-	18	86/-	35	79/-	209
,, . . .	14 × 8	18	58/-	22	47/-	18	57/-	20	53/-	312
,, . . .	14 × 7					17	46/-	18	43/-	358
Doubles . . .	13 × 7	14½	42/-	17	34/-	13	41/-	16	38/-	400
,, . . .	12 × 8	15½	39/-	18	31/-					380

		FESTINIOG SLATES.				CARNARVON SLATES.				No. of Slates per sqr. 2½ lap.
		1st quality.		2nd quality.		1st quality.		2nd quality.		
			Price.		Price.	Weight.	Price.	Weight.	Price.	
						cwts.		cwts.		
Princesses . .	24 × 14		242/-			55½	270/-	73	235/-	96
Duchesses . .	24 × 12		210/-		188/-	48	233/-	64	217/-	112
Marchionesses . .	22 × 12		178/-		155/-	44	198/-	55	182/-	124
,, . .	22 × 11		167/-		135/-	40	184/-	52	160/-	133
,, . .	20 × 12					40	184/-	48	160/-	135
Countesses . .	20 × 10				120/-	32	164/-	43	145/-	164
,, . . .	18 × 12					34	158/-	46	145/-	155
Viscountesses . .	18 × 10					28	130/-	38	113/-	186
,, . .	18 × 9				88/-	25	105/-	35	103/-	210
,, . .	16 × 12					29	126/-	37	113/-	178
Ladies . . .	16 × 10		93/-			25	100/-	34	99/-	214
,, . . .	16 × 9					22	87/-			238
,, . . .	16 × 8				58/-	20	79/-	27	68/-	266
,, . . .	14 × 10					22	80/-	25	65/-	253
,, . . .	14 × 8		55/-		45/-	18	56/-	22	54/-	312
Doubles . . .	13 × 7					15	42/-	17	39/-	400
,, . . .	12 × 8					16	36/-			380

The following table gives the comparative cost of Duchess, Countess, and Princess, best Bangor slating, 2½ lap—

PRINCESS SLATING, 24 × 14.

	£	s.	d.	
96 Princess Slates at 260/- per M.	1	4	11½	
112 feet run of Plate Lath, at 2/6	0	2	9½	
¾ lbs. Lath Nails, at 3d.	0	0	2¼	
1½ lbs. Copper Nails, at 10d.	0	1	3	
Labour per sq.—Slater 5s., Labourer 3s., at ·50	0	4	0	
				£1 13 2¼

COUNTESS SLATING, 20 × 10.

	£	s.	d.	
164 Countess Slates, at 167/- per M.	1	7	4½	
173 feet run of Lath, at 2/6	0	3	5	
1 lb. Lath Nails, at 3d.	0	0	3	
2 lbs. Copper Nails, at 10d.	0	1	8	
Labour per square, at 8s., ·55	0	4	5	
				£1 17 1½

DUCHESS SLATING, 24 × 12.

	£	s.	d.	
112 Duchess Slates at 236/- per M.	1	6	5	
112 feet run Slate Lath, at 2/6	0	2	9½	
¾ lb. Lath Nails, at 3d.	0	0	2¼	
1¾ lbs. Slate Nails, at 3d.	0	1	5½	
Labour per square, as before, 8/- ·50	0	4	0	
				£1 14 10¼

The following are the number of each kind of slates which will fill a narrow gauge box truck, viz.—

	1st quality.	2nd quality.		1st quality.	2nd quality.
24 × 14	1750	1500	16 × 10	4000	3000
24 × 12	2000	1500	16 × 8	5000	3500
22 × 12	2250	1750	14 × 12	3750	2750
22 × 11	2500	2000	14 × 8	5500	4500
20 × 10	3000	2250	13 × 10	5000	3750
18 × 10	5000	2500	13 × 7	7000	5500
18 × 9	4000	3000	12 × 8	6500	5500

A good slate, like a brick when of good quality, will, when struck, give off a clear ringing sound. It is also hard and rough to the touch, while a bad quality has a smooth, greasy feel. Their relative

value may be ascertained by weighing at a certain temperature, plunging them in water for 12 hours, and then, after drying, re-weighing them. Those which have absorbed the least water being the most valuable. The upper surface of a slate is called its back, the under its bed, the upper edge its head, the lower its tail. As before mentioned the ridge, hips, and valleys may be made watertight with lead, but often this is done by Broseley or other tiles. The ridge-cress as they are termed, are shown at *a* (Fig. 43A) or they may have a plain round roll as at *b*, or fitted with loose ornaments cemented in a groove provided for the purpose as at *c*. Slate slabs are sometimes sawn and used as at *d*, and lately the best form of this kind we have yet seen is prepared as at *e*. Their cost is from 10d. to 1s. 3d. per foot run fixed.

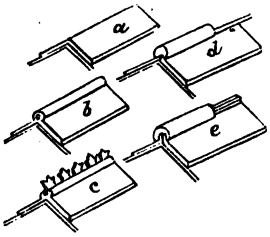


Fig. 43A

PANTILING is a term used for the covering of a roof with tiles of a rectangular outline, but having both a convex and concave surface, so that as they are laid one laps over the other, forming a series of ridges and valleys, running from ridge to eaves of roof (see Fig. 44)

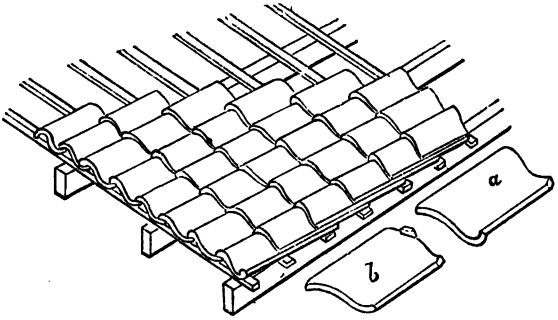


Fig. 44.

in which *a* is the upper side of the pantile and *b* the under side; they are hung on laths same as in slates, their size being usually 14 inches long and 10 inches broad; the lap is usually from 2 to 3 inches, and the number per square is given in the annexed table:—

	No. of Pantiles to a square.	Pt. of $1\frac{1}{2} \times 1$ in. lath per square.	Nails per square.	Constant of labour to be multiplied by the wages per day of a bricklayer and labourer.	
				Laid dry.	Pointed inside and out.
Pantiling, 10 in. gauge	180	180	125	·422	·790
,, 11 ,,	164	164	115	·422	·790
,, 12 ,,	150	150	100	·422	·790

PLAIN TILES are of a rectangular form, having a flat surface usually about $10\frac{1}{2} \times 6\frac{1}{2}$ or 11×7 and $\frac{5}{8}$ thick. (See Fig. 45.) Some hang simply on laths, as described in pantiling, while others are holed for nails or pegs. They are laid with a lap varying from 3 inches to 4 inches, with or without a bedding in mortar. Their lower edges are often cut to various fancy patterns (see Fig. 46), and are then called

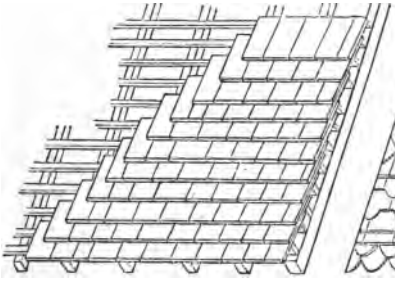


Fig. 45.

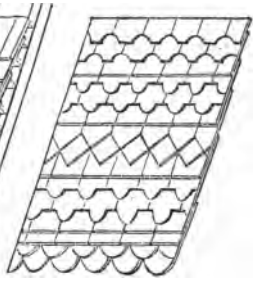


Fig. 46.

ornamental tiles. They are of two colours, generally brown and blue, and the following table gives the labour and number per square.

	Number per sq.	Feet of $1\frac{1}{2} \times \frac{1}{2}$ in. lath per square.	Nails per square.	Value of constants of labour of bricklayer and labourer per day.
Plain tiling, $10\frac{1}{2} \times 6\frac{1}{2}$, 4 in. gauge	600	300	150	·739
,, ,, $3\frac{1}{2}$,,	700	350	175	·764
,, ,, 3 ,,	800	400	200	·790

The Roman and corrugated tiles are laid in a similar way, and are shown in Figs. 47 and 48—*a* showing the upper surface, *b* the under-

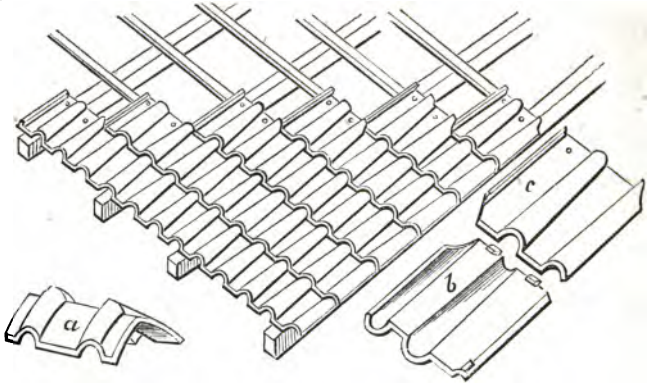


Fig. 47.

surface, and *c* the ridge tile in each case. These, owing to their large size, are usually nailed down. It takes 85 of them to a square, their size being 16½ inches × 14 inches. They are of two colours, red and dun-coloured, and are sometimes glazed.

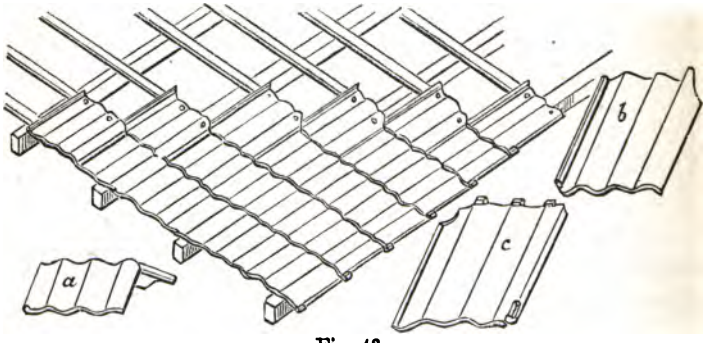


Fig. 48.

The following gives the comparative cost of plain, pan, and Roman tiling :—

PLAIN TILING, 3½ GAUGE.

	£	s.	d.	
700 Tiles, at 32/- per M.	1	2	5	
350 feet of 1¼ and ½ Laths, at 1/2	0	4	3	
1½ hundred of Nails and Tile Pins	0	1	6	
3 hods of Mortar	0	2	6	
Labour, at 8/- 764	0	6	1	
				£1 16 9

PAN TILING.

	£	s.	d.	
164 Tiles, at 140/- per M.	1	2	11	
164 feet run of 1½ and 1 Lath, at 2/4	0	3	9	
1⅙ hundred of Nails	0	1	2	
2 hods of Mortar..	0	1	8	
Labour at 8/- ·790	0	6	3	
				£1 15 9

Greek and corrugated tiles come nearly to the same price per square as pantiling.

The prices of tiles are usually as follows, viz.—

		No. to a square.	Crest 12 in. long.
Red Roman tiles .. .. .. per 1,000	140/-	85	5/6 per dozen
Do. dun coloured .. .. .. ,,	170/-	,,	6/6 ,,
Do. black glazed .. .. .. ,,	200/-	,,	
Brown Broseley plain tiles .. ,,	32/-	600	
Do. do. blue .. .. ,,	34/-	,,	
Ornamental do. brown .. ,,	33/-	,,	
Do. do. blue .. .. ,,	35/-	,,	
Plain blue crest, 20 in. long, per dozen	5/6		
Flanged ,, ,, .. ,,	7 -		
Roll ,, ,, .. ,,	7/6		
Grooved roll with ornaments, 20 in. long .. .. ,,	11/6		

ROOFING FELT is a substance composed largely of hair saturated with an asphalte composition, and should be chosen more for closeness of texture than excessive thickness. It is sold in rolls 2 feet 8 inches wide and 25 yards long, thus containing 200 feet super in a roll. Before the felt is laid on the boards a coating composition composed of the following mixture—

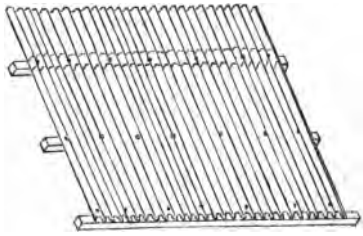
5 lbs. Ground Whiting, 1 gallon of Coal Tar .. } Boiled to expel the Water.

is applied, while still warm slightly on the boards themselves, the felt is then laid on, taking care to stretch it smooth and tight, and the outside edge is nailed closely with ⅞ zinc or tinned tacks. The second width of felt laps the first an inch at least, the joint receiving a little of the composition, and the tacks pass through both thicknesses of felt, and so on till the whole of the roof is covered. Then the whole requires a coat of the composition, and in three or four weeks a second

or finishing coat, when it will require nothing for three or four years, but should receive one the moment it begins to bleach. The gutters and ridge are generally in two thicknesses of felt. A dry day should be selected for the work. Its cost per square, including boarding, can be arrived at as follows, viz. :—

	£	s.	d.	
100 feet super $\frac{3}{4}$ Boarding	0	9	6	
Labour laying same	0	2	6	
105 feet of super Felt, at 7/8	0	7	8	
$12\frac{1}{3}$ lbs. of Whiting at 1d.	0	1	$0\frac{1}{3}$	
$2\frac{1}{2}$ gallons of Tar, at 3d.	0	0	$7\frac{1}{2}$	
Labour, mixing, and boiling ditto	0	0	9	
300 1 inch Jacks, weight $1\frac{1}{8}$ lbs. at 3d.	0	0	$3\frac{1}{4}$	
Labour, laying Felt per square	0	2	6	
				£1 4 $10\frac{1}{4}$

Zinc as a covering for roofs compares well with galvanized iron, which is liable to oxidation, no painting being required. It has been weighed, after being in place 24 years and the loss of metal owing to atmospherical influences found only to be $\frac{1}{2}$ an oz. to a foot super. ; in fact, it cannot wear out by rust. It takes less timber or iron framing than any other covering, and a square of roofing weighs when laid about $\frac{1}{5}$th of the same quantity of pantiling or slating and $\frac{1}{12}$th of plain tiling. If a zinc roof has a fall of 1 in 7 no drip is required, but simply a fold at the junction of the sheets ; in flats a fall of not less than 1 in 24 should be given. The nature of this metal allows it to be worked readily, and the joints can be easily soldered. Sheets for roofing are when plain generally 7 or 8 feet long and 3 feet wide, so that when corrugated with 3 inch corrugations, as in Fig. 49, it will cover



Fig, 49,

2 feet 6 inches, the same when the sheets are rolled in the Italian pattern Fig. 50, 4 inches in the length of each sheet is taken up by the

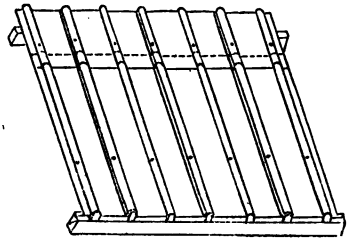


Fig. 50.

lap. When laid on boarding with cap joint as in Fig. 51, the sheet turned up at the edges with roll added, will cover 2 feet 10½ inches from centre to centre of roll.

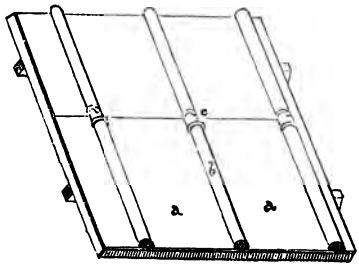


Fig. 51.

The comparative nett cost of Italian and corrugated zinc laid on rolls, and that laid on boarding with roll caps will be as follows, the thickness of the zinc gauge when compared with the Birmingham wire gauge being as given in the two first columns :—

		No. of squares per ton after corrugation, about	Weight per square when laid, including all corrugations and laps.		
			With plain roll cap.	With drawn roll cap.	With Italian or ordinary corrugation.
B W G	Zinc				
21	No. 13	14¾	160	165	160
20	,, 14	12¾	180	185	185
19	,, 15	11¾	195	200	200
18	,, 16	10¾	215	220	220

ITALIAN AND CORRUGATED ON ROLLS.

Zinc, No. 13, at £24 per ton	1	13	6	
Fastenings	0	3	0	
Ridge Cap, about	0	3	6	
Wood rolls (80 ft.)..	0	7	6	
Fixing	0	9	0	
				£2 16 6

LAID WITH PLAIN ROLL CAP.

Zinc. No. 13, at £24 per ton, as before	1	13	10	
Ridge Cap, about	0	3	6	
Wood Rolls (33 ft.)	0	4	6	
Roll Cap and fastenings	0	6	6	
¾ Boarding laid	0	12	6	
Labour, fixing..	0	9	0	
				£3 9 10

The following table gives approximate cost of zinc roofing fixed:—

B.W. Gauge	21	20	19	18	Per Square, to which add cost of Boarding.
Zinc Gauge..	13	14	15	16	
Plain Roll Cap	56/-	61/-	66/-	71/-	
Patent Drawn Roll Cap ..	70 -	75/-	80/-	85/-	
Italian & other Corrugation	57/-	62/-	67/-	72/-	

Thus roofs laid with drawn roll cap will cost about 14s. more than a plain roll cap. 14 or 15 gauge, that is 20 or 19 B W G, should be used in roofs, but for gutters, &c., nothing less than 15 or 16 zinc gauge. Zinc roofing has this advantage compared with corrugated iron, that the old zinc when taken off is worth about one-half its original value as old metal.

Corrugated iron buildings (see Fig. 49).—The timber work of both corrugated and zinc covered buildings may be made, as stated before, very light. 3 inch framing for walls up to 8 or 9 feet, and 4 inch framing up to 11 feet, larger of course in wide buildings and warehouses. The sheets are fastened to the sill plate and transoms, consequently the posts may be 8 or even 10 feet apart. For sheds and stores no inside lining is required, but for dwelling-houses, schools, churches, &c., it is essential an interior lining of match boarding be

adopted, leaving a space of three or four inches between the outside sheets and the lining. With this provision the building will be cool in summer and warm in winter in any climate. The interior lining may be wrought and painted, or rough and covered with canvas, and finished with paper hanging. Floors, doors, and windows are the same as in ordinary dwelling-houses. The usual thickness for this sheeting and approximate cost are given below. The sheets are made from 4 to 7 feet long with 3-inch or 5-inch flutes; the former chiefly

	Usual rate per ton.	Weight per foot super after corrugation, about	Weight to cover a square allowing for all laps.	Cost per square, fixed complete.
		lb. ozs.	cwts. qrs. lbs.	£ s. d.
18 B W G	22 10 0	2 10	2 2 3	3 2 0
20 ,,	22 15 0	2 2	2 0 0	2 17 6
22 ,,	24 0 0	1 13	1 2 20	2 15 0
24 ,,	24 15 0	1 6	1 1 14	2 10 0

Curving iron sheets, £1 per ton extra.
Punching ditto, sides and ends, £1, ditto.
Rivets, burrs, nails and screws, cost extra about 4s. per square.
Ridge copping, 8d. to 1s. per foot run.

CHAPTER IV.

Joiner's Work, Technical Terms, Doors and Door Frames, Sashes, Skylights, Cased Frames, Casements, Shutters, Bay Windows, Staircases, Cisterns, Tanks, Fencing, and Gates.

JOINERY is the art of joining pieces of timber by *morticing, grooving, dovetailing,* &c., and fastening them by *gluing, wedging, pinning,* and *nailing,* and includes the framing of wood for the external and internal finishings of buildings in contradistinction to carpenter's work, which latter is of such a nature as not to be removed without affecting the stability of a building. Joiner's work, therefore, may be so removed. The quality of the work of a joiner depends mostly upon using seasoned wood; and, secondly, only on the workmanship.

The principal joiner's work in a building, after the roof is on, are the floors, doors, windows, skylights, and staircases; such work requires more accuracy than carpenter's, being subject to closer inspection. All is, therefore, carefully fitted, and the exposed surfaces made perfectly smooth. The chief terms used are *morticing* and *tenoning* (see Fig. 52). M M, being the mortices; T T, the tenons; and S S, the shoulders.

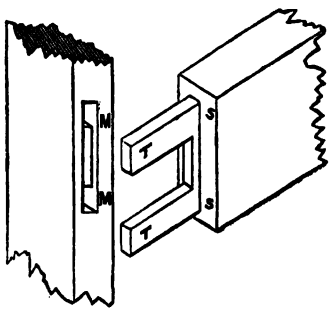


Fig. 52.

MITRING is the forming the diagonal joint which two pieces make when meeting at an angle, such as the mitred border to fire places, &c. See Fig. 53.

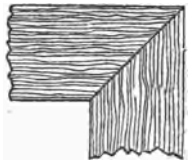


Fig. 53.

SHOOTING is making the edge of a board perfectly straight.

DOVETAILING is joining two pieces of framing by indenting, as in Fig. 54.

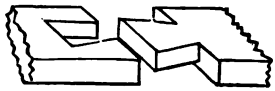
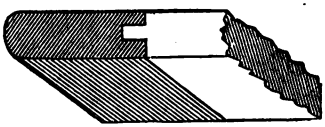
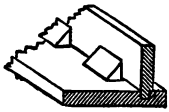


Fig. 54.

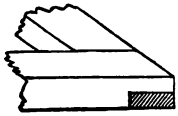
CLAMPING is a mode of fastening several boards by another placed transversely at each end by mortice or tenon, or by a groove and tongue, thus—



BLOCKINGS are small pieces glued to the interior angle of two boards to strengthen the joint, thus—



HOUSING is the cutting of a piece out of one board for the insertion of the end of another, thus—



DOORS AND DOOR FRAMES.—A door is a piece of framing of equal thickness joined and nailed together, so as to enclose a space or spaces. The upright and horizontal pieces of this framing are respectively called stiles and rails; and the thin filling pieces, panels. Ledged doors, shown in Fig. 52, which shows a ledged and braced door, are the commonest kind of doors. The horizontal boards are the ledges; the diagonal, the braces: they are generally made 1 inch in thickness.

Panel doors may be of 4, 6, 8, or more panels; each panel not ex-

ceeding 12 inches wide, or 3 feet long, if it can be avoided by the use of more framing. Figs. 53, 54, 55, and 56, all represent 4 panel doors. In Fig. 53, the framing simply projects before the panel with

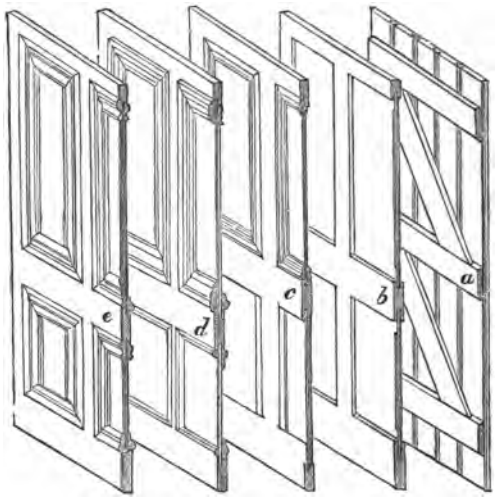


Fig. 56. Fig. 55. Fig. 54. Fig. 53. Fig. 52.

a square edge, and is called square framed; Fig. 54 has mouldings inserted in both sides of the top panels, while the lower panels are two-thirds the thickness of the doors, with a bead on the upright edge; hence it is double moulded top panels, the bottom panels being bead butt and square. Fig. 55 has a moulding planted on the upper panel which projects from the framing, and the bead of the lower panel is carried round the horizontal joint; hence, it is a bolection moulded one side top panel and bead flush lower panel, and simply moulded other side. In Fig. 56, to add to their appearance, the panels have a margin sloped off all round them, so that the framing, not more prominent than their centre part, might project and throw shadow on them. This moulding also projects, so that on one side it is a bolection moulded raised panel, and simply moulded other side. When the edge of a piece of square framing is pared off diagonally, it is termed chamfering; and when this diagonal face does not mitre round the corners, but stops short to avoid weakening the junctions, it

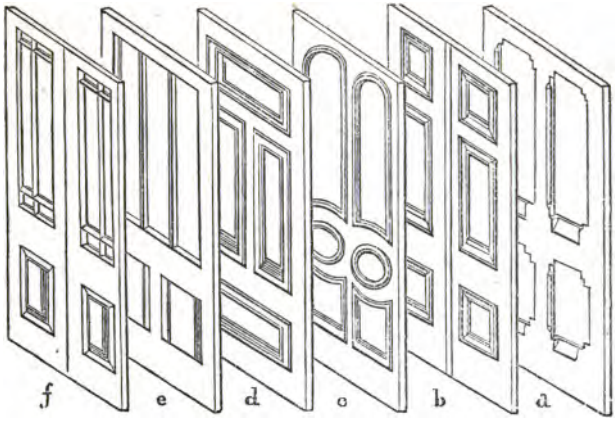


Fig. 57.

is called stop chamfering—*a*, Fig. 57, therefore, represents a stop-chamfered door; *b*, *c*, and *d*, same fig., represent various styles of front doors, which are usually made of red deal, in contradistinction to internal doors, which are oftener of American yellow pine, than any other kind of timber; *e* and *f*, same fig., are common greenhouse doors, the former having top part open for glass; the latter door is shown folding, that is, hinged at both stiles and rebated at the joints; this is also open at top panels for glass, with margin all round for the in-

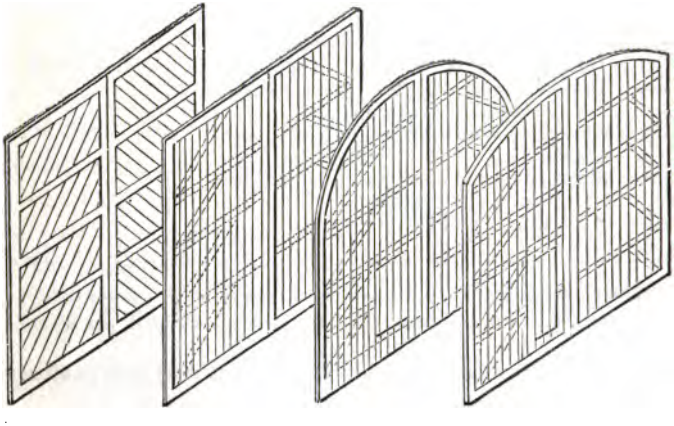


Fig. 63. Fig. 64. Fig. 65. Fig. 66.

sertion of stained or ornamental glass. Large doors, such as are used for warehouses, coach-houses, &c., are generally called *framed and filled in*, the framing being stouter than the above, accordingly as they are larger, and the weight is thrust on to the stiles and hinges by diagonals; they are generally filled in with matched and beaded boarding (the middle rails and diagonals being less than the styles by the thickness of this boarding), which can also be placed diagonally, as shown in Fig. 63; or vertical, as Figs. 64, 65, and 66. Figs. 63 and 64 are square headed; Fig. 65, circular headed; and Fig. 66, segmental headed. In these large doors, a small wicket-door is usually inserted. The following are the prices of doors ready made:—

	Thickness so called, at per foot run.							
	1¼ in.	1½ in.	1¾ in.		2 in.			
	d.	d.	s.	d.	s.	d.		
4-Panel. Square framed	6¼	6¾		7½		8½		
do. Single moulded	7¼	7¾		8¾		10		
do. Double moulded	8	8¾		9¾		11¼		
do. Bead butt all one side and square, or Bead butt both sides lower panels & sq.	..	8¾		9¾		11¼		
do. do. do. and moulded, or Bead butt all over	..	9¾		10¾	1	0¼		
do. Bead butt and bolection moulded ..	..	10½		11¾	1	0½		
do. Bead flush all one side and square, or do. Bead flush both sides lower panels & sq.	..	9		10		11½		
do. do. do. and moulded, or Bead flush all over	..	10¼		11¼	1	0¾		
do. Bead flush and bolection moulded ..	..	11¼	1	0	1	1½		
do. Double marginal door, moulded ..	..	..	1	0	1	1		
do. Raised panel, and bolection moulded one side and moulded other ..								
do. Raised panel and bolection moulded both sides								
do. Stop chamfered one side and moulded other								
do do. both sides								

Circular-headed doors are about double the price of square doors.

15 per cent. extra if six-panelled. 10 per cent. extra if the framing is of red deal.

(Yellow pine panels and moulding are used generally, except otherwise specified.)

If made out of best selected timber, or prepared for staining or varnishing, 10 per cent. extra is charged.

RED DEAL LEDGED DOORS.

	Thickness so called.	
	1 inch.	1¼ inch.
	d.	d.
Ledged doors with three ledges	5½	7¼
Ledged and braced doors, or with four ledges ..	6	8

	If above 100 ft. super in one door.	If from 50ft to 100ft. super in one door.		If less than 50ft. super in one door.	
	d.	s.	d.	s.	d.
2 in. framed and filled-in doors, at per ft. sup.	7		8½		10¾
2½ in. do. do. dó. do.	8½		10½	1	1
3 ,, do. do. do. do.	9¼	1	1¼	1	6

The prices of these framed and filled-in doors below 50 ft. super each will vary according to size.

Fig. 67.

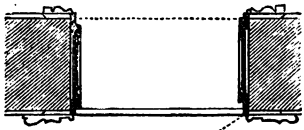


Fig. 68.

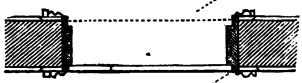


Fig. 69.

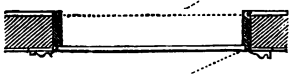
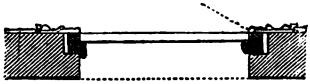


Fig. 70.

Fig. 71.



In fixing doors, frames are required to fasten the hinges to, and to allow of that nice fitting which is rendered necessary to prevent passage of weather to the internal portions of dwelling-rooms. They are generally, when made, solid; half a brick in thickness; say, 4½ by 3, as in Figs. 67 and 73, representing a rebated and beaded doorframe; the moulding planted on is called an architrave, which is shown to be grooved to receive and hold the plaster of the walls. These frames have often, for halls, a fanlight framed at top, as in Fig. 74, which is called a segmental-headed door-frame, with transom. Fig. 70 shows a door fixed in the commonest

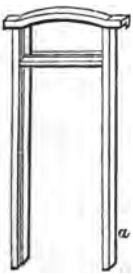


Fig. 74.

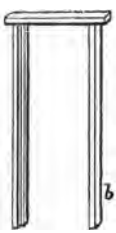


Fig. 73.

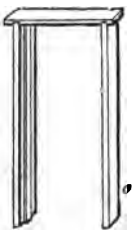


Fig. 72.

way for a wood building. In this case, there is simply a stop for the door to shut against. Frames for internal doors are seen in Figs. 69, 70, 71, and 72; these are called jamb linings. Fig. 69 being single, and Fig. 70 double rebated; these are generally 1½ inch thick, and from 1½ to 2 inches wider than the bare wall to allow of the band moulding finishing on their edge. The bevelled pieces of timber, called grounds, are used to hold and stop the plaster of the walls, or the edge of the jamb may be grooved, as shown at Fig. 69. Sometimes, where the walls are unusually thick, these jamb linings are framed, as shown in Fig. 67; the top, bottom, and middle rails and general finish of panels being uniform with the doors. The following are the prices of door frames at the manufactory:—

YELLOW PINE DOOR FRAMES, JAMB LININGS, ETC.

If primed, add ½d. per foot extra.

				d.						d.
3½ by 2½	rebated,	per ft.	run	3	5	,, 4	rebated,	per ft.	run	6¼
3½ ,, 3	do.	do.		3½	5½	,, 1½	do.	do.		2¾
4 ,, 3	do.	do.		4	5½	,, 3	do.	do.		5½
4½ ,, 3	do.	do.		4½	5½	,, 4	do.	do.		7½
4½ ,, 4	do.	do.		6	6	,, 1¼	do.	do.		2½
5 ,, 1¼	do.	do.		2½	6	,, 1½	do.	do.		3
5 ,, 2	do.	do.		3½	9	,, 2½	do.	do.		7½
5 ,, 3	do.	do.		5	11	,, 1½	do.	do.		5½

WINDOW SASHES.—Sashes are those parts of a window which receive the glass and generally open and shut; the glass is placed in

Fig. 79.

Fig. 75.

Fig. 76.

Fig. 77.

Fig. 73

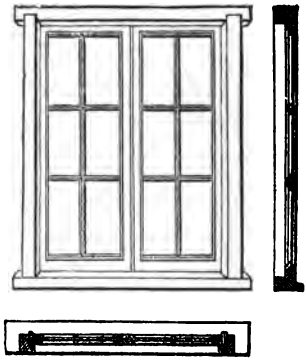


Fig. 82.

Fig. 80.

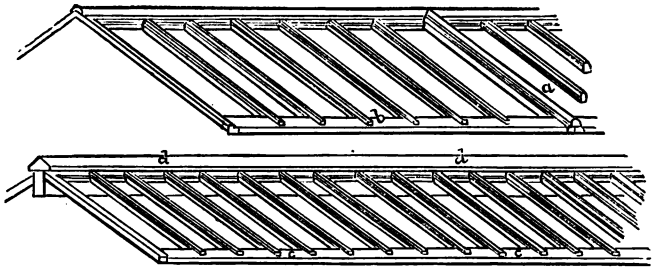


Fig. 81.

rebates, and the sash bars; stiles and rails are moulded on the inside in various forms; the most common being the plain, chamfer, ovolo, lamb's tongue, the astragal, and hollow. Fig. 75 is a sash; Figs. 76, 77, and 78 are fan-lights to go in door frames; Fig. 79 is a greenhouse roof-light, strengthened in two places by light rods of iron passed through the stiles and bars. Figs. 80 and 81 are skylights which may be either framed as the latter, in short lengths, with a cover over the joint; or the top and bottom rail may be continuous, as

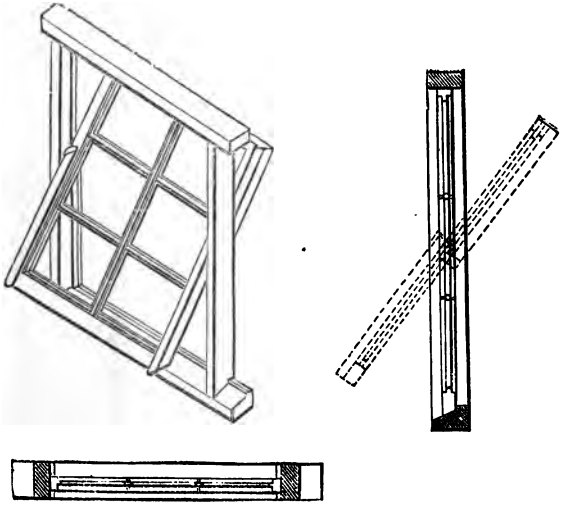


Fig. 83.

in Fig. 81, and more economical, especially if the bars are tenoned into the ridge direct, as shown. In roof-lights generally, the bottom rail is made thinner than any other part, to allow of the ends of the glass coming over it and the lead flashing.

Casement, or French Lights, are composed of sashes hung to a solid rebated frame by means of hinges (see Fig. 82). One or both of them may be thus hung, the joint at the centre of each sash being also rebated to keep out the weather. The lower part of the frame is the *sill*, which has one of its faces bevelled to throw off the water quickly; the upper part is called the *head*. Figs. 83 and 84 are other modifications of sashes with solid frames, the former swinging on pivots for ventilation, as in workshops, and the latter having the upper part of the sash hanging on the lower, commonly used in hospitals. Fig. 87 represents a highly-finished casement and frame, fit for a library or other ground floor, or balcony opening. The joint, both at top and bottom of the casement, is protected from the weather by a projected nosing, commonly adopted by continental joiners while at the bottom sill any water entering issues out again through the piece of piping inserted in the sill for that purpose.

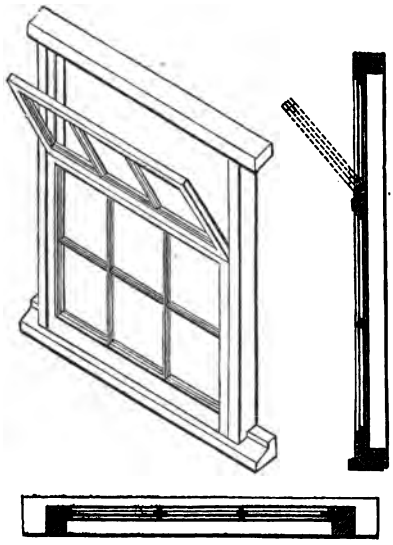


Fig. 84.

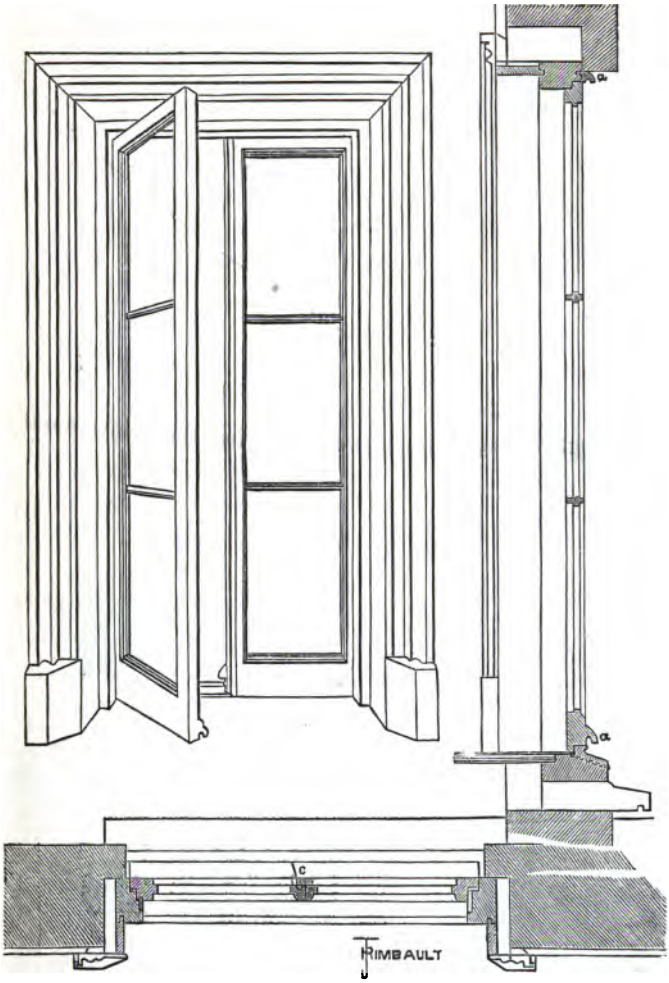


Fig. 87.

We now come to the most useful form of windows for dwelling-houses, namely, sashes and cased frames, in which the sashes are divided into two parts, the top sliding past the bottom in two distinct grooves provided for that purpose. When only one sash is moveable, they are called *single hung;* when both move, *double hung.* They are ordered by the thickness of the sash, a pair of 1½ sashes and frame

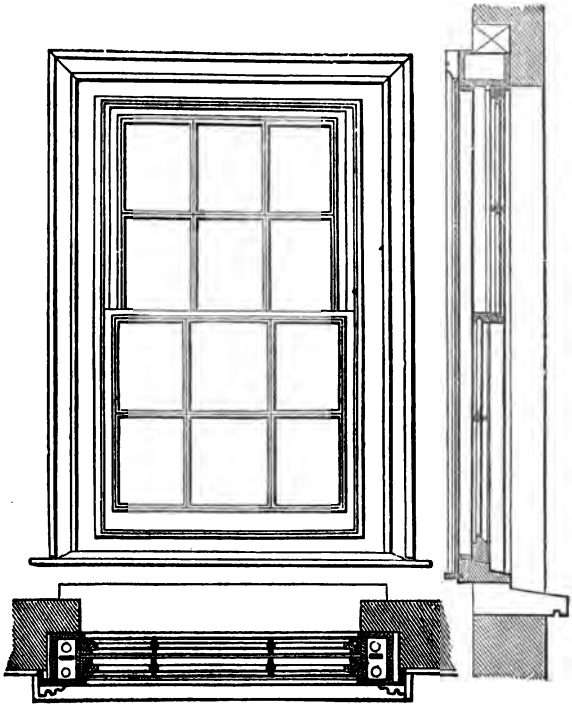


Fig. 85.

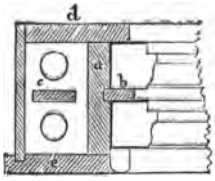


Fig. 86.

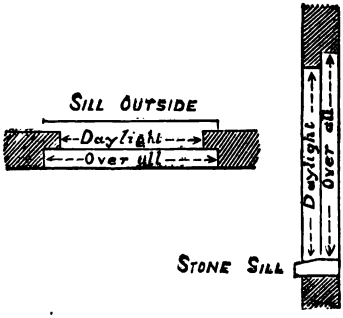


Fig. 86*a*.

having sashes $1\frac{1}{2}$ inch thick. The sashes are hung by cords passing over pulleys, and attached to balance weights concealed on the back of the case. In the enlarged section (Fig. 86), *a* is called the pully-

piece, and on the face of this the sashes work, separated from each other by the parting slip *b*, thus enabling them to pass each other without touching. The strip *c* acts in the same way for the weights. The pieces *d* and *e* are called the front and back linings. In the best make the sills and pulley pieces are made of oak. There are two modes of measurement—"daylight," which is the length given from the face of stone sill, or under side of wood sill, to the under side of head, and in clear of pulley stiles; and "over all size," which is from under side of sill over the top of frame, and taking the width also over the frame (see Fig. 86*a*). The axle pulleys may be of brass or iron, but a cheap axle pulley is very false economy. Hempen sash cords are used generally, but twisted copper wire and even chains are specially made for very heavy sashes, the latter being the best, and least liable to accident. Weights are made usually of cast iron, but when they become too large, lead is preferred. The spaces in the sash to receive glass are called panes, and in Fig. 85 we show the simplest make of a pair of sashes and frame with 12 panes, fitted in a 9-inch wall. The window board is there grooved into the sill, and the band moulding finishes on it, the edges of the frame being made good to the wall by a strip

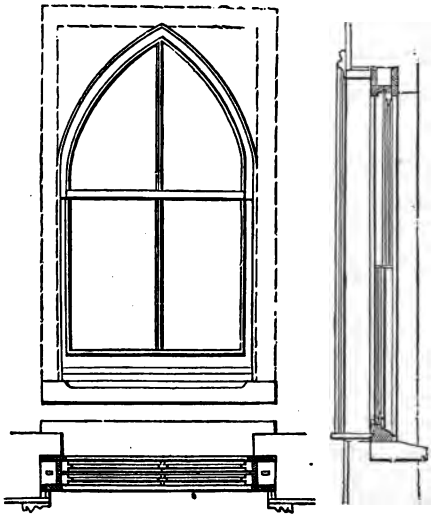


Fig. 90.

nailed on all round. Sashes and frames, in addition to being made square-headed, as in Fig. 85, may be segmental headed, as in Fig. 88, semi-headed, as in Fig. 89, or gothic-headed, as in Fig. 90, and the best mode in each case is to have the sash-frame made square, and the

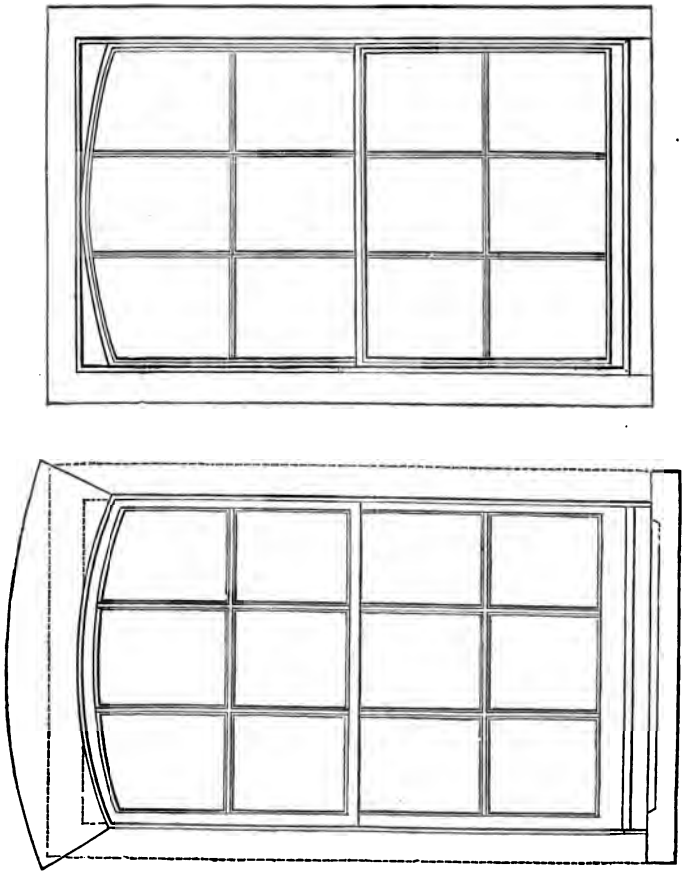
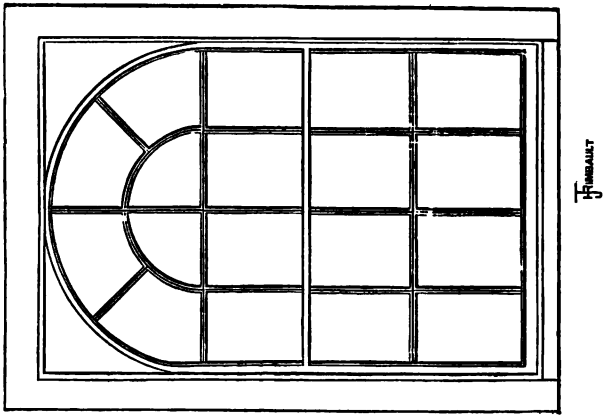


Fig. 88.

corners of the upper portion of both the sash and frame filled in to suit the external contour of the brick or stone-work, as shown in the dotted lines. The sashes themselves not only slide easier in this way, but there is a considerable saving in the cost of manufacturing them.



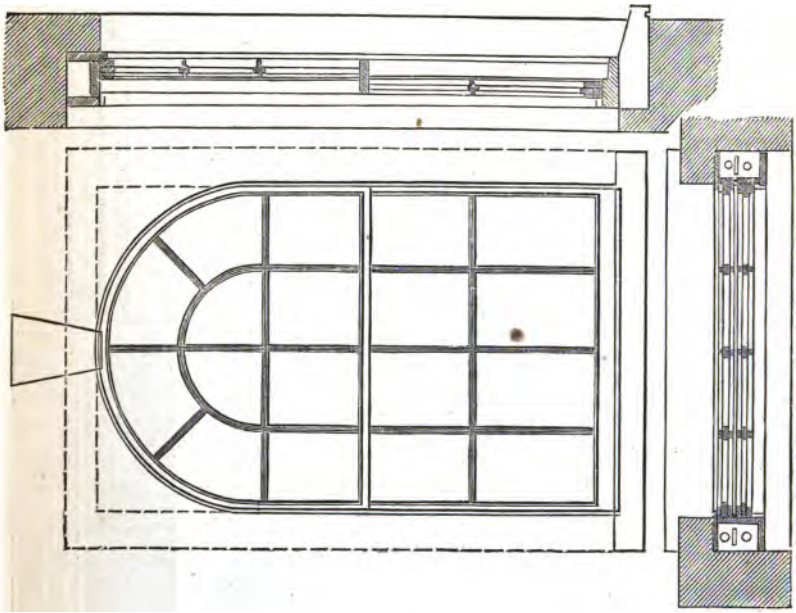


Fig. 89.

Fig. 91 represents a pair of sashes and frames, with sliding shutters, hung with lines and weights in a precisely similar mode to that of the sashes, and thus forming a double set of cased frames. The joists and floor are often cut in this way in order to give depth sufficient to allow

Fig. 91.

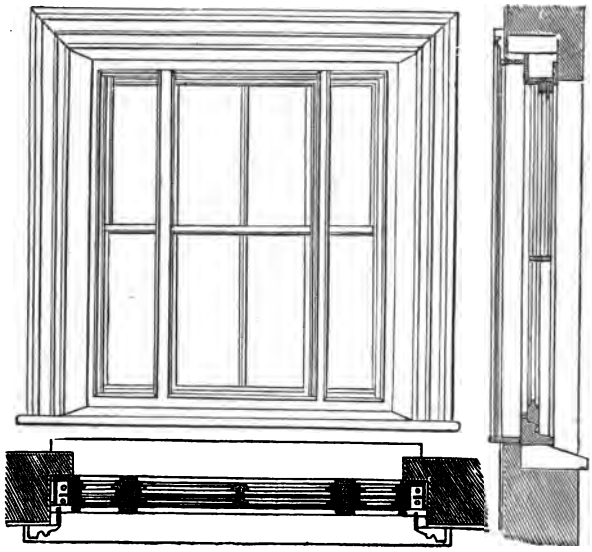


Fig. 92.

of the shutters sinking below the window sill. The piece of framing concealing the shutters when down is called the *window back.* When a window is divided into two or three portions longitudinally, as in Fig. 92, they are called Venetian sashes and frames, and the two centre upright pieces of framing are termed mullions, and in this case the centre sashes only being hung, the sash-cord passes over the top of the side sashes into the outside cased frame. In Fig. 93 we have a similar pair of Venetian sashes and frame, but with all the sashes hung. In addition to this there are folding shutters provided, which fold back into what are called boxings or linings, attached to the wall specially for the purpose. In this case again a window-back from the sill to the floor is required, and elbows, as the pieces of framing are called which fill in the space from the lower edge of the shutters to the floor. At the top, panelling is also required for the *soffit,* as it is termed. Those portions of the shutters which fold into the wall are called *back flaps.* A cant, or bay window, is one in which the side-lights are arranged at an angle to the front light, which projects beyond the exterior surface of the house, thus extending the angle of vision

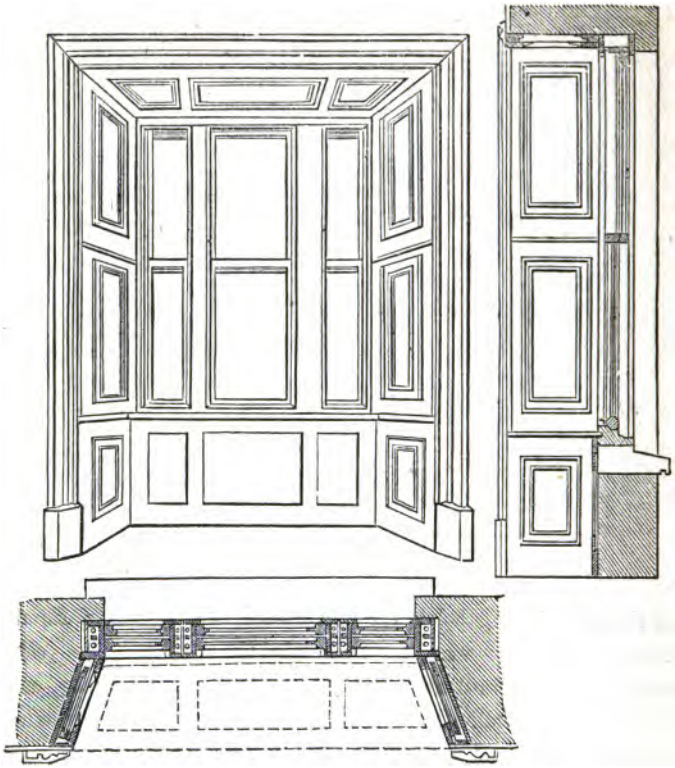
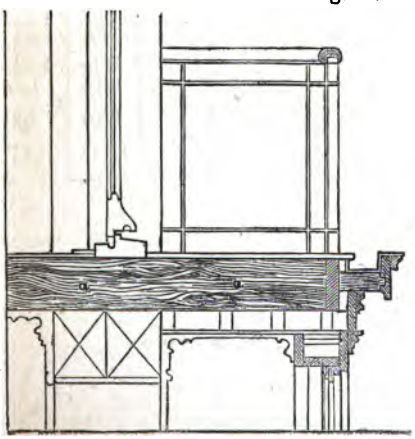


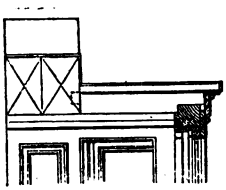
Fig. 93.

from the interior; and Fig. 94 is one of this kind, the folding shutters, backs and elbows, soffit, &c., being shown. The mullions in one case are shown of stone, which is necessary with a stone balustrade. Sometimes, however, the next floor joists are carried over the projecting window, and rest on its frame, as at B, and with railing, the top surface leaded, becomes a verandah. Again, at C, the top of window is merely covered with lead or zinc laid on boarding. In either of the two last modes no stone mullions are necessary, and the cased frames may be made as shown at D, an ornamental wood pillar, or other ornament, covering the join at angles, and protecting it from the weather.

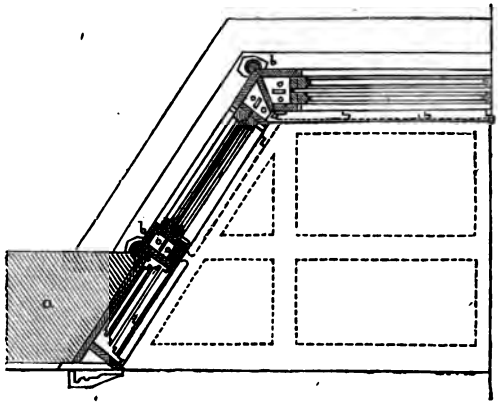
Fig. 94.



B.



C.



D.

The following gives the prices of sashes and frames at the manufactory :—

SASHES AND FRAMES, MEASURED OVER ALL.

					If above 25 feet super in one sash frame.	If from 15 feet to 25 feet super in 1 frame.	If less than 15 ft. super in a frame.
1½ in. sashes and frames,			single-hung,	per foot super	8½d.	9¼d.	11½d.
1½	ditto		double-hung,	do. do.	9d.	10d.	1/0½
2	ditto		single-hung,	do. do.	9½d.	11¼d.	1/2
2	ditto		double-hung,	do. do.	10d.	1/-	1/3
1½ do. with 1 mullion,			single-hung,	do. do.	9¾d.	1/-	1/1
1½	do.	do.	double-hung,	do. do.	10½d.	1/0½	1 3
2	do.	do.	single-hung,	do. do.	11¾d.	1/1	1 4
2	do.	do.	double-hung,	do. do.	1/0¾	1/2	15½
1½ do. with 2 mullions,			single-hung,	do. do.	9½d.	11¾d.	1/0½
1½	do.	do.	double-hung,	do. do.	10¼d.	1/-	1/2½
2	do.	do.	single-hung,	do. do.	11½d.	1/0½	1/3½
2	do.	do.	double-hung,	do. do.	1/0¼	1/1¾	1/4
2 circular-headed sashes and frames 4 or 5 panes wide, double-hung				do. do.	1/8	1/10	2/2
2½	do.	do.	do.	do. do.	1/9	1/11½	2/4½

If primed add ½d. per foot super.
If glazed with 15 oz. glass, add 4d. per foot.
Do. ,, 21 ,, ,, 6d. ,,
If oak (best foreign) sills are ordered, add ¾d. per foot super.
If with back linings and parting slips, ,, ¼d. ,,
If with lines and weights .. .. .. ,, 2d. ,,
If with moulded horns to sashes .. ,, 3d. per horn.

FRENCH AND SLIDING CASEMENTS.

(With solid frames up to 12 inches in section).

	If above 25 feet super in a casement.	If from 15 feet to 25 ft. super in a casement.	If less than 15 ft. super in a casement.
1½ in. casement, with solid frames, at per ft. super	8d.	9d.	10½d.
2 ,, ,, ,, ,, ,,	9½d.	10½d.	11¾d.
1½ ,, Sliding casement .. .. .. ,, ,,	10½d.	11d.	1/0½
2 ,, ,, ,, ... ,, ,,	1/-	1/0½	1/1½

If primed, add ½d. per foot super.
If glazed with 15 oz. glass, add 4d. per foot.
Do. ,, 21 ,, ,, 6d. ,,

SASHES WITHOUT FRAMES AND FANLIGHTS.

	If above 25 feet super in a light.	If from 15 ft. to 25 feet super in a light.	If less than 5 ft. super in a light.
1½ in. square sashes or fanlights, at per foot super	3¾d.	4½d.	5½d.
2 ,, ,, ,, ,, ,,	5d.	6d.	7¼d.

If primed, add ½d. per foot super.
If glazed with 15 oz. glass, add 4d. per foot.
Do. ,, 21 ,, ,, 6d. ,,

GREENHOUSE LIGHTS AND SKYLIGHTS.

	If above 25 feet super in a light.	If less than 25 ft. super in a light
at per foot super		
2 in. skylights, with bars from 6 in. to 9 in. apart ..	3¼d.	4½d.
2½ ,, ,, ,, ,, ,, ..	4¼d.	5¾d.
2 ,, ,, ,, 9 in. to 15 in. apart ..	3d.	4d.
2½ ,, ,, ,, ,, ,, ..	4d.	5½d.
2 continuous light	2¾d.	3¾d.
2½ ,, ,, ...	3¼d.	4½d.

Iron stays supplied and screwed on above at ¼d. per foot super.
If primed, add ½d. per foot super.
If glazed with 15 oz. glass, add 4d. per foot.
Do. ,, 21 ,, ,, 6d. ,,

YELLOW PINE CUPBOARD FRONTS, SQUARE FRAMED MOULDED AND VENETIAN SHUTTERS, CASINGS, FRAMED LININGS, &c.

If primed add ¾d. per foot super.

	If over 25 feet super in 1 piece.	If from 15 feet to 25 feet super in 1 piece.	If from 10 ft. to 15 feet super in 1 piece.
1 in. square framed .. .. at per foot super	6d.	7d.	8¾d.
1 ,, single moulded .. .. ,, ,,	6¾d.	7¾d.	9½d.
1¼ ,, square framed .. .. ,, ,,	6¼d.	7½d.	9¼d.
1¼ ,, single moulded .. .. ,, ,,	7¾d.	8¼d.	10d.
1½ ,, Venetian shutters .. .. ,, ,,	8½d.	9½d.	11d.
2 ,, ,, ,, ... ,, ,,	10d.	11d.	1/0½

The prices of these shutters, &c., below 10 feet super each, will vary according to size.

We now come to the means of passing from one floor to another by means of *staircases*, which are formed of *risers*, morticed into *treads*, the latter overhanging generally with a *nosing*, which is usually rounded and moulded. These treads and risers are supported by means of *string boards*, one placed against the wall, and called the wall string, the other at the outer ends, called the outer string. The treads and risers are always housed into the wall string, but the outer string is usually cut away to receive them. When this is not the case, the outer string becomes a *close string*. Fig. 95 represents a staircase in two flights, with a landing or resting-place quarter space. If a semicircle was passed in going from one flight to the next, this landing would then be termed a half space: the four treads which turn round the circular well-hole, are called winders being narrower at the inner end and wider next the wall. The carriages shown in the figure in dotted lines are pieces of scantling placed beneath the steps, and following the pitch of the staircase to give firmness to the flight. The handrail is the bar supported by slender uprights, called balusters, to protect the outer edge of the staircase, and guide persons ascending and descending the stairs. Rigidity is given to this rail by an iron newel at the curtail step, or first step, by which the stair is ascended, generally finished for this purpose by a scroll, as shown. A few of the

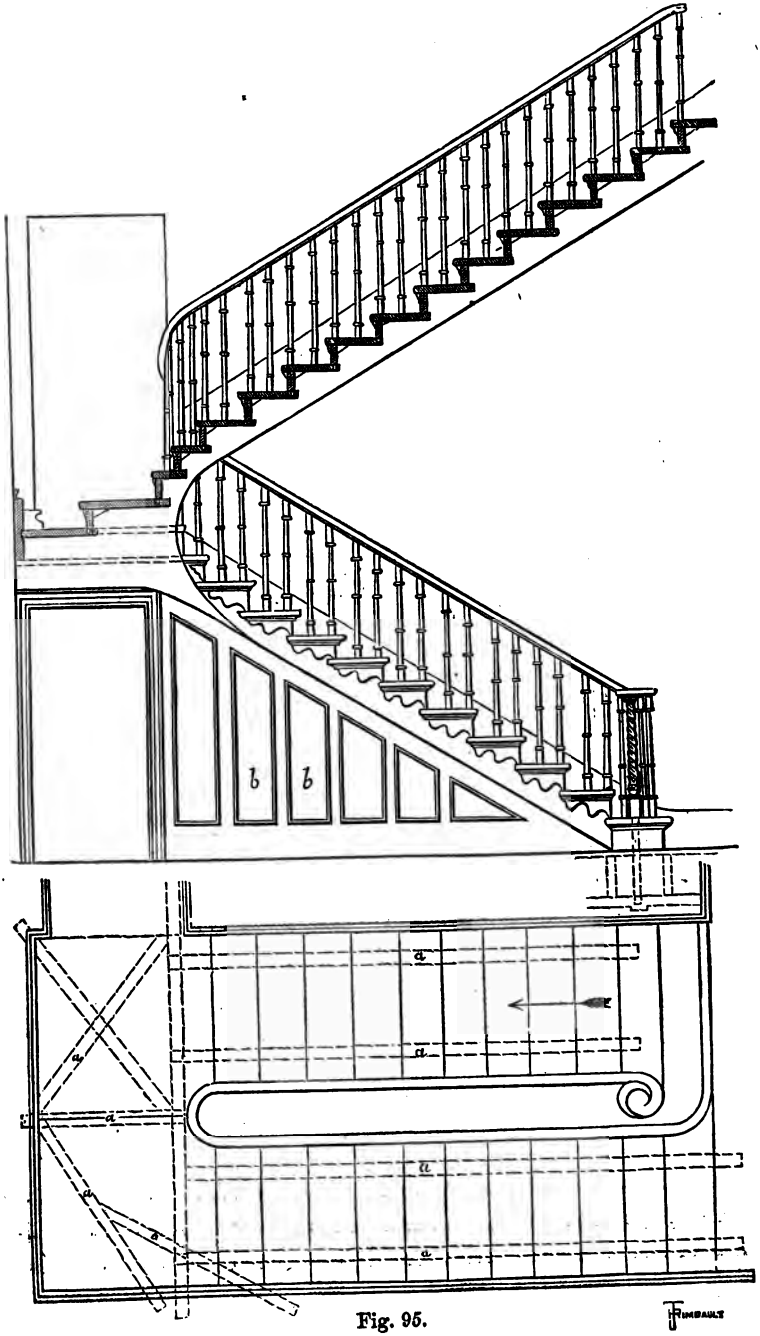


Fig. 95.

FINEBAULT

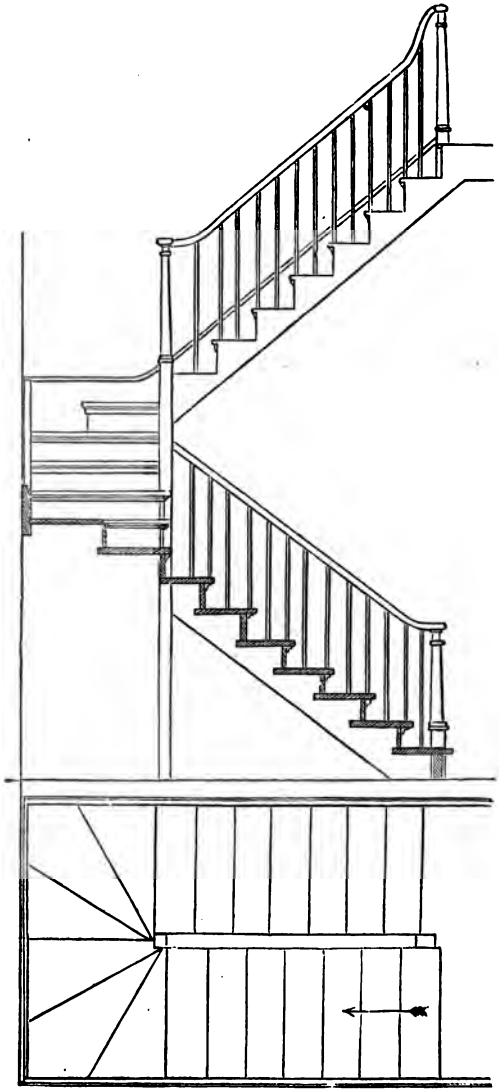


Fig. 96.

balusters are generally also of iron, firmly screwed to the strings for the same purpose. Where the handrail is continued round the well-hole of a staircase, the part where it turns round the well is termed

the *wreath.* A ramp is where the handrail makes a sudden rise as in framing it into a newel post. Fig. 96 shows a commoner stair turning round a newel post, and termed a *dog-legged staircase.* The solid newel post takes the place of the well-hole in this case, and into this the string-boards are framed.

Cisterns are required for sundry purposes, and although now oftener made of slate or galvanized iron, these may in some cases be too expensive or not easily procured. Fig. 97 shows the ordinary wood cistern lined with lead; while Fig. 98 is a larger one often required in

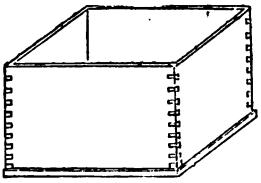


Fig. 97.

Fig. 98.

manufactures. The latter is composed of thick planks or deals strongly bound with bolts, and serviceable for holding corrosive liquids which would injuriously affect iron. Figs. 99 and 100 show a fencing, which is not only neat in appearance, but easily fixed; consisting simply of straight laths pegged together in a lattice fashion, and supported in place by posts and rails; the former being placed

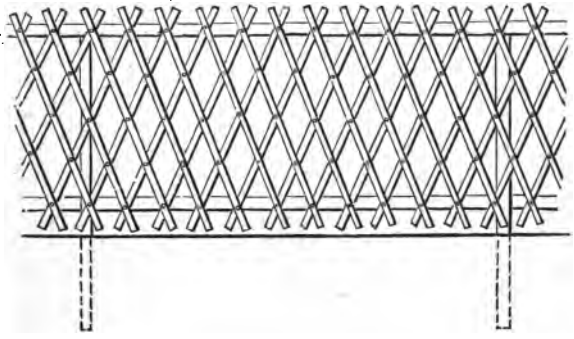


Fig. 99.

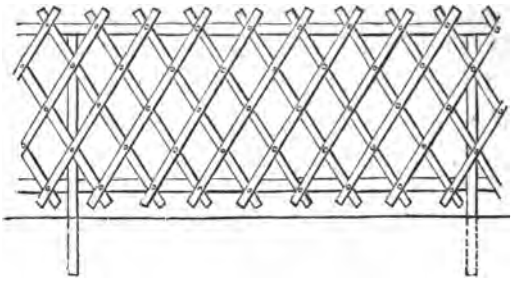


Fig. 100.

every eight or ten feet apart, and well let into the ground; the laths are in each of the figures of the same length and size; but the spaces being more stretched in the latter figure, the fencing becomes cheaper.

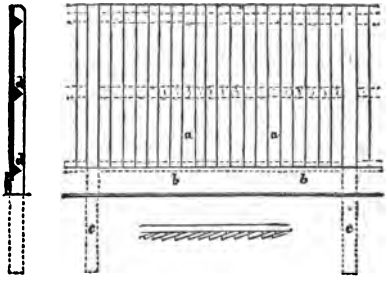


Fig. 101.

Fig. 101 shows a fencing suitable for inclosing a gentleman's park or extensive grounds, and is often made of oak; the upright pales being cleft. Fig. 102 is of a much cheaper kind, and is used for tempo-

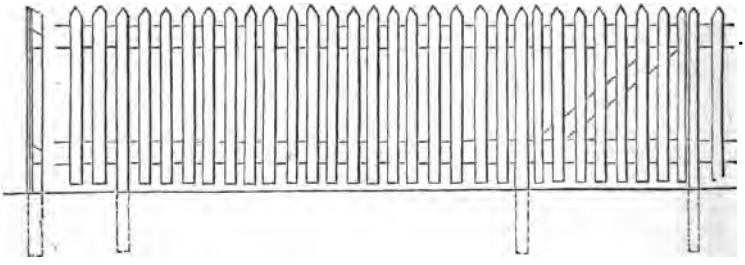


Fig. 102.

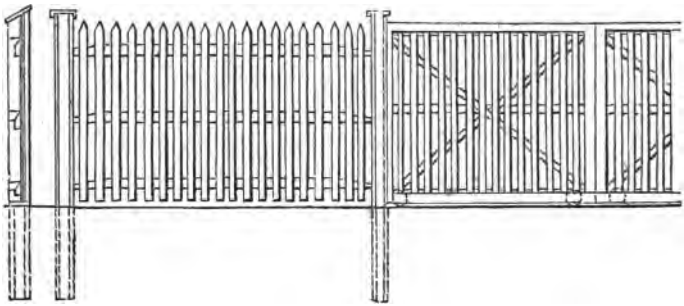


Fig. 103.

rarily fencing in cultivated land, such as gardens, &c. Fig. 103 is known as the timber merchant's fence, pockets being provided on each side of the posts for the ends of the rails to slip into. Any of the bays of the fencing can thus be taken out, and the posts being simply let into sockets formed in the ground can be readily removed and put

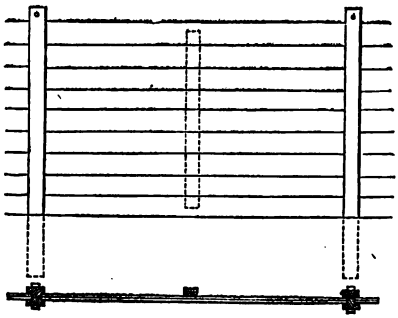


Fig. 104.

up again. Fig. 104 is another system of temporary fencing largely used for agricultural shows and the like, and forms the most economical barrier that can be made; the boarding not requiring to have a single nail driven in it, is in reality little or no worse for being thus used. Figs. 105, 106, 107, and 108, are designs for entrance gates which, well executed, forms a prominent feature in the outward appearance of a gentleman's grounds. The value of gates similar to these, containing 50 feet super, say 10 feet wide by 5 feet high, would be from £6 to £8.

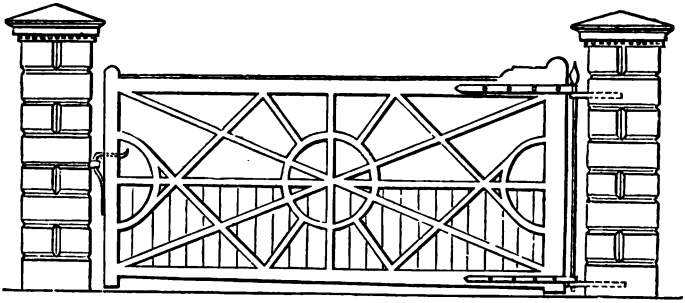


Fig. 105.

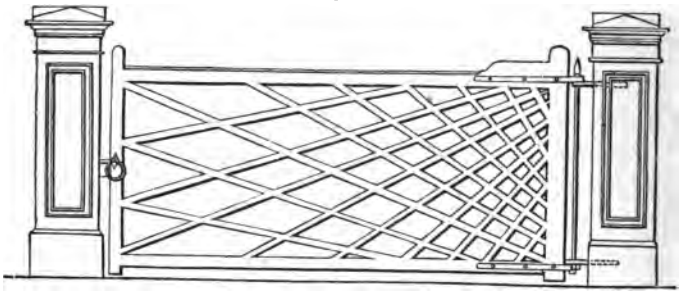


Fig. 106.

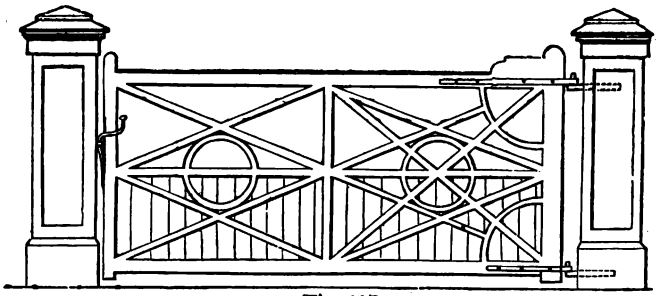


Fig. 107.

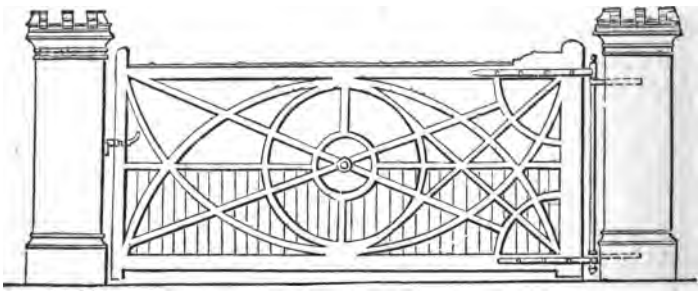


Fig. 108.

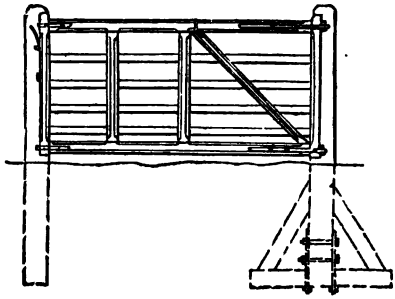


Fig. 109.

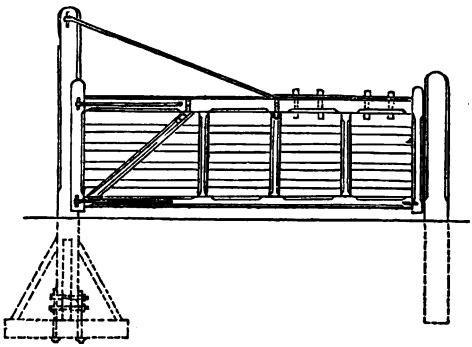


Fig. 110.

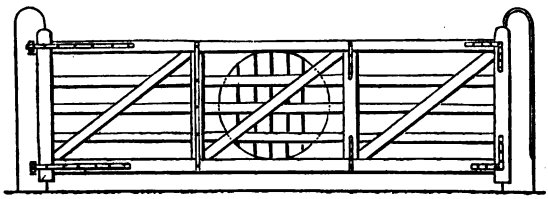


Fig. 111.

A sketch of the common field gate is given in Fig. 109, and level crossing gates for main line or branch railways in Figs. 110 and 111.

And now a word as to temporary buildings.

In many instances, where time is an object, and when owing to the difficulty in procuring the stone, bricks, &c., necessary for the erection of more permanent buildings, it is found necessary to fall back upon structures composed chiefly of timber, easily erected, and

whose value, with proper care and attention, need not deteriorate. A temporary wood building should, however, in no case exceed one storey in height, and the framing should be very similar to that used in the wood partitions of ordinary dwelling houses, shown in Fig. 112.

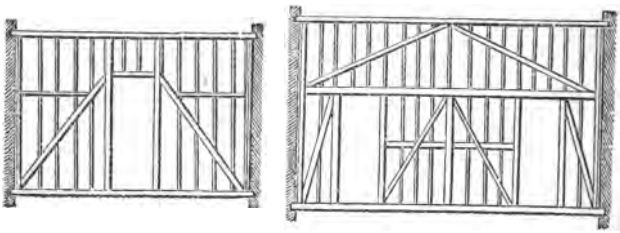


Fig. 112.

The clear spaces between the uprights should not exceed 15 inches, and the walls should be well tied with diagonal braces. A little attention to the proper housing of the sills, and the morticing of the uprights, and heads to doors and windows, with careful bracing, is all that is required to ensure good work. All corner posts, door, and window posts should be for buildings up to 8 feet high, at least 4 × 3; but the intermediate posts, whose object it is simply to carry the outer and inner boarding, need not exceed two inches in thickness, say, 4 × 2. We give at the end of this work various designs for churches, cricket pavilions, schools, warehouses, &c., all of which are daily in request throughout the country. These buildings are often constructed with iron framing, but this is chiefly done when they are destined for erection in hot climates, and where the cost of transit to the interior may be expensive. The roofs generally are of zinc, corrugated iron, or slates, but oftener of wood and felt properly prepared and laid. We ourselves prefer slates in most cases for the roof, and decidedly object to either iron or zinc being used for the sides and ends of these buildings. In fact, nothing is more economical or capable of being well fitted round the necessary openings for the doors and windows than boarding, and we recommend in all cases where the buildings are used constantly as living rooms, that the interior throughout be lined with thin boarding. In powder mills a light roof is absolutely necessary to allow (in the

event of an explosion) for its disastrous effects being expended as far as possible towards the sky where the least damage may be expected. Such a boarding as is shown in Fig. 113 was designed expressly with this

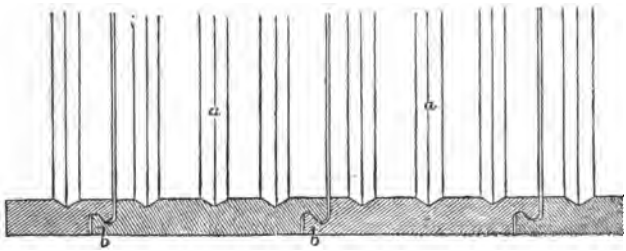


Fig. 113.

object in view. It is styled *wave joint boarding*, and has been very extensively and successfully laid. The surface rain water falling on each board runs down the furrows *a a*, while the grooved joint *b b* not only also facilitates this, but keeps the substance forming the board

Fig. 114.

always dry in itself. Simpler kinds of wood roof and side boarding are shown in Fig. 114, the ordinary 1 inch or $\frac{3}{4}$ inch board, in 7 and 9 inch widths, being used with a lap joint, or placed close to each other with a fillet over the joint to exclude the rain water. Either of these, well laid, will be perfectly water tight. Fig. 115 gives a sketch showing the various boardings used generally in the sides of this class of buildings, each kind being known as *weather boarding*, the thicker piece at the base being known as the *plinth*. *a* may be simply composed of floor boards laid with a lap joint. *b*, *c*, and *d* are

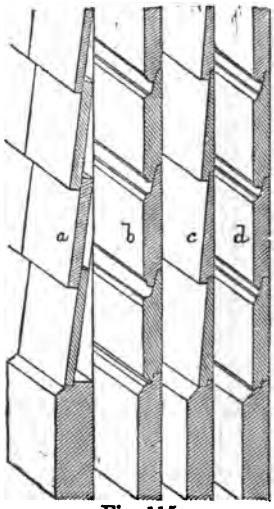


Fig. 115.

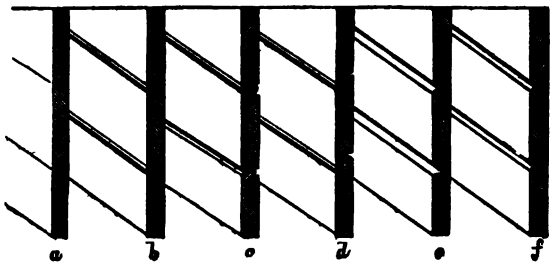


Fig. 116.

prepared specially by machinery for the purpose. *c* is the most economical kind, since two are generally taken from one board after it has passed through the machine, one-half of the machine labour being saved. The interior linings may be made as delineated in Fig. 116. Sometimes the inside of the rooms are papered, and in that case the joint should be simply matched as shown at *a*. When painted or stained and varnished the joint is improved by the insertion of the bead at *b*, and where the

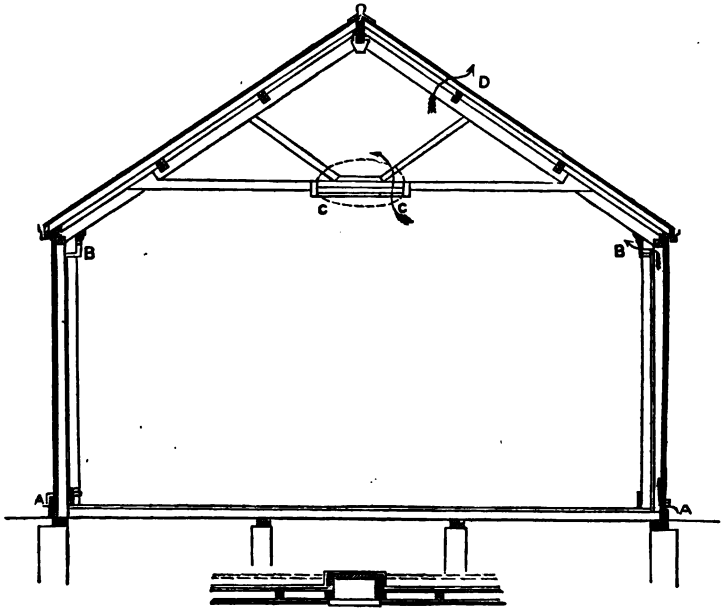


Fig. 117.

boarding is seen on both sides the bead is placed on both edges as at *c*; *d*, *e*, and *f*, are simply various other modes of improving the appearance of the joint. Perhaps one of the most called for temporary buildings is that required as an hospital, on the serious break out of a fever or other epidemic. In these cases it is above all things extremely desirable to ensure a good thorough system of ventilation throughout the wards, and too much cannot be insisted upon by all poor law and other inspectors with a view to its being ensured. Fig. 117 shows one of the most approved methods of arriving at this result. The external air is first admitted through gratings at A, distributed over the outside of the building, and then passes up the closed pilaster to issue out of the perforated cornice, running the whole length of the ward at B. Its tendency is to force the heated and unwholesome air through ventilators swinging on centres provided in the ceiling, and to gradually disperse them through the joints in the slates at D, which will be found amply sufficient for this purpose. This we have ourselves seen tested over and over again in rooms purposely filled with smoke, and so strong is the current at the ventilator outside, that small pieces of paper loosely held there will be taken up the pilaster into the room. Fig. 118 gives an idea of the

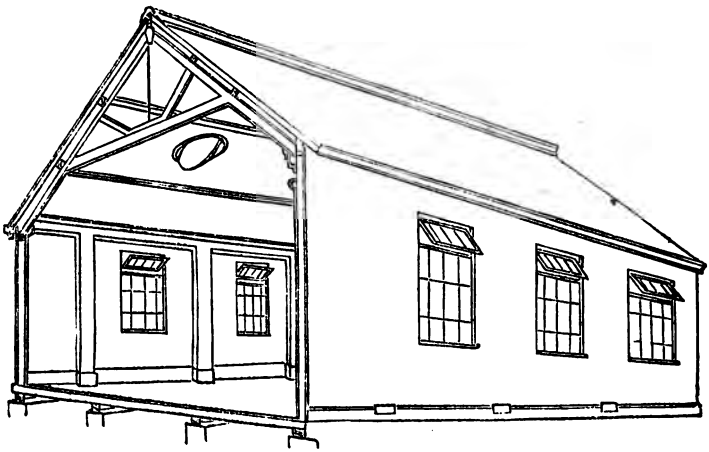


Fig. 118.

internal appearance of these buildings, and shows the pilaster and ventilator in the roof.

We give in Figs. 119, 120, and 121 some designs for the forms and school desks necessary to the fitting of the various

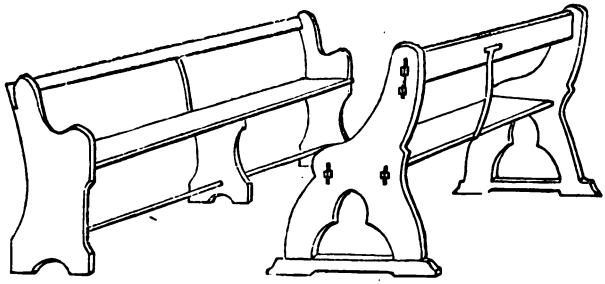


Fig. 119.

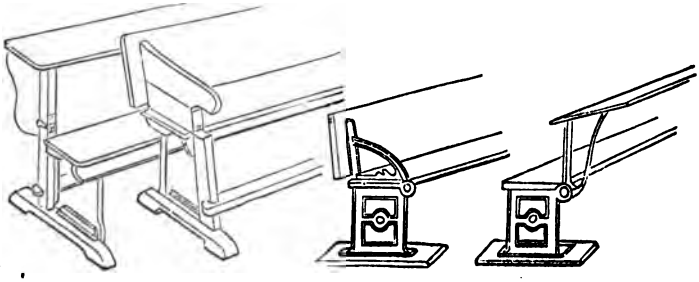


Fig. 120.

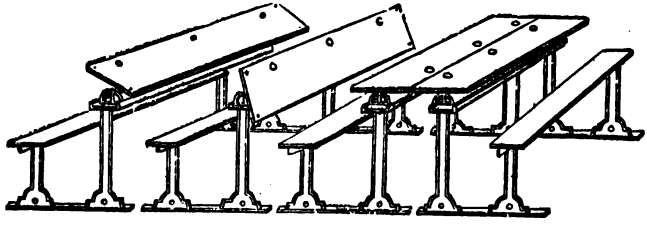


Fig. 121.

school-rooms shown at the end of this work. Those shown in the two latter figures are so arranged as to be used either as double or single school desks, and the desk portion by being hinged may be made to act as a back to the seat. Numerous varieties of these are to be

found exhibited at the South Kensington Museum, nearly all of them having some more or less commendable features. As regards Church fittings, nearly all architects design seats specially

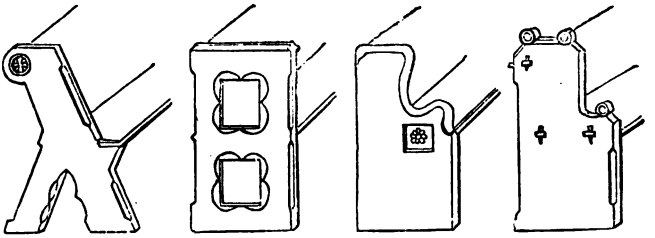


Fig. 121A.

adapted to the particular character of the building for which they are intended. Fig. 121A gives a few of the usual kind of bench ends;

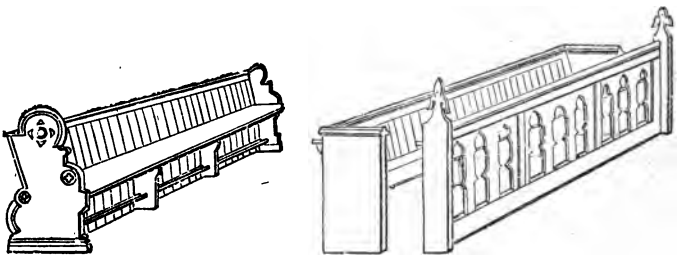


Fig. 122.

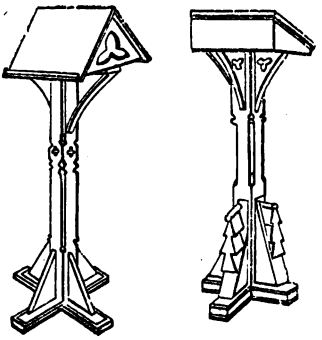


Fig. 123.

and Fig. 122 the seats generally in use. We should recommend in all cases the use of pitch pine or best yellow pine for these, if well prepared, cleaned and varnished, the natural graining and colour of the wood itself will enhance the effect. Fig. 123 shows the lectern, and Fig. 124 the reading desk, which should also be carried out in the same material unless the building is of such a permanent character as to

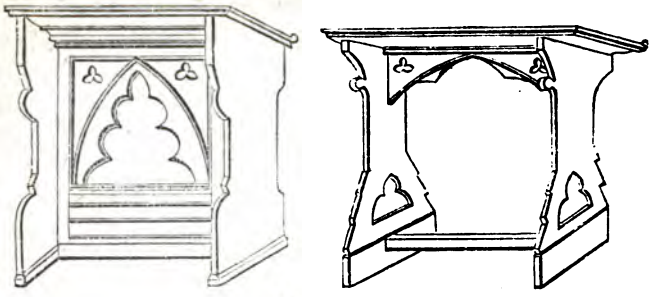


Fig. 124.

demand increased display in its fittings. When that is the case, either oak or cedar wood should be preferred as being better ornamented. Figs. 125 and 126 are effective pulpits, but these, of course, are varied

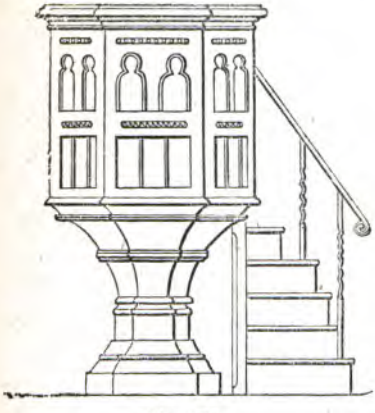


Fig. 125.

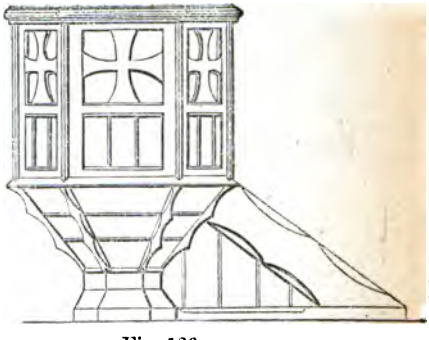


Fig. 126.

as to design greatly. With the Communion altars and rails shown in Figs. 127, 128, and 129, we conclude the portion of joiners' work chiefly necessary to the fittings of the various buildings. We ourselves consider that pitch pine is one of the most suitable woods for these fittings. Dry and well-seasoned it is very durable, and any amount of variation in tint and graining may be given. Let it also be simply varnished.

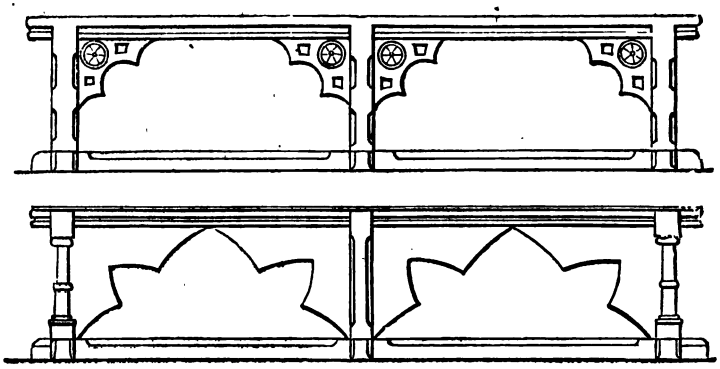


Fig. 127.

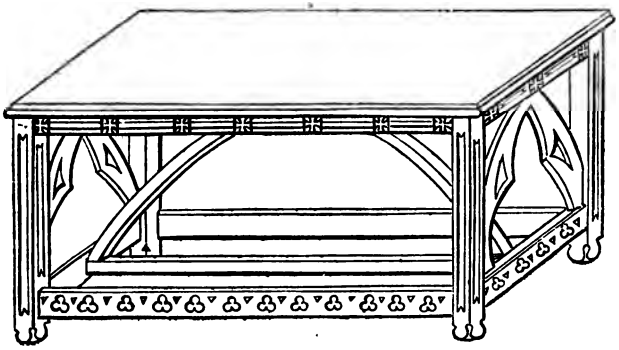


Fig. 128.

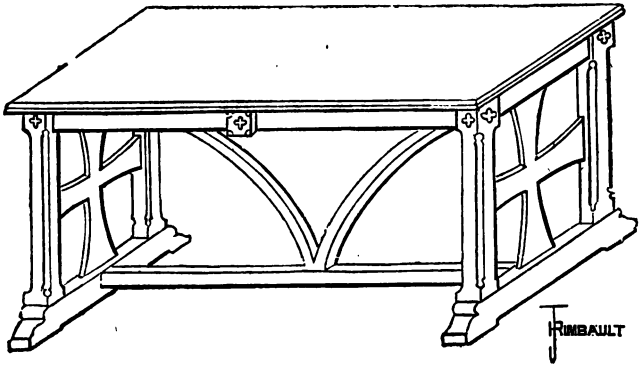


Fig. 129.

CHAPTER V.

CONTRACTORS' PLANT.

Excavation. Measurement of same. Cost of Labour. Barrows. Carts. Tip Wagons. Cranes and Pile Drivers.

THERE are but few buildings of any kind but involve, as a preliminary, the excavating of the soil necessary in order to get the foundations on a solid basis; and in railways, water-works, &c., this is often the chief item of the contract. The labour of digging deep and throwing out of trenches in the foundations of buildings will increase with the depth, and it is usual to allow for additional prices to every throw of five or six feet in height. Excavation is paid for by the cube yard, or 3 feet × 3 feet × 3 feet, again called a single load, and the wheeling, carting, filling in and ramming to foundations and drains form all separate items charged as extras. The nature of the soil will affect the amount of excavation one man can perform in a day, but in loose ground 10 cube yards, and where hacking with the pick is required from three to five yards cube will be a fair day's work. Filling into barrows and wheeling is estimated by the run of 20 yards, every 20 yards beyond the first run being charged extra. With two men filling and one man wheeling 30 yards per day can be removed to the end of the first run, and the labour beyond that can be calculated according to distance by allowing one man extra to every run. For example—What will be the cost of labour only in removing 500 yards of soil a distance of 300 feet, the men's wages being at the rate of 3s. 6d. per day, and 30 yards removed to the end of the first run being a good day's work? Dividing the full distance, 100 yards, in this case by 20, we get the number of wheelers viz., 5, to this add the two fillers, making 7 altogether at 3s. 6d. = £1 4s. 6d. Then as 30 yards cube = £1 4s. 6d., 500 yards will

cost £20 8s. 4d, The estimate of filling into carts and carting away is rated at so much for the first mile, a reduced charge being made for each and every mile beyond the first, much in the same way as filling and wheeling barrows described above. Where planking and strutting is required to hold the sides of deep trenches, the cost is either added to the price for digging or it may be a separate item at per foot run. N.B.—A cubic yard *before* excavation will occupy from $1\frac{1}{4}$ to $1\frac{1}{2}$ cube yards *after* being excavated, but will gradually assume its usual bulk in embankments. As a more reliable guide to the cost of excavation generally, we give below the constants of labour for this work.

	Days of a Ground Labourer or Navvy.
EXCAVATING ONLY—PER CUBIC YARD.	
Vegetable earth	·045
Loam (sand and clay mixed)	·060
Clay	·100
Earth, mixed with coarse gravel, &c.	·150
Chalk	·200
Rock requiring blasting	·450
THROWING WITH A SHOVEL TO A HEIGHT OF FIVE FEET, OR FILLING TRUCKS—PER CUBIC YARD.	
Vegetable earth, loam, or sand	·048
Hard earth, clay, &c.	·055
Mud in a wet state	·065
FILLING BARROWS—PER CUBIC YARD.	Days of a Ground Labourer.
Vegetable earth, loam, or sand	·045
Clay, stony earth, &c.	·052
Mud in a wet state	·061
REMOVING TWENTY-FIVE YARDS WITH WHEELBARROWS, DEPOSITING, AND RETURNING—PER CUBIC YARD.	
Vegetable earth or loam	·026
Clay, stony earth, sand, or mud	·030
RAMMING EARTH—PER CUBIC YARD.	
Vegetable earth, loam, or sand, in layers 6 in. thick	·040
Do. do. do. in layers 12 in. thick	·025
CLAY PUDDLE—PER CUBIC YARD.	
Tempering and spreading in layers 9 in. thick	·650
Do. do. in layers 12 in. thick	·550

TURF ABOUT FOUR INCHES THICK—PER SUPERFICIAL YARD.	Days of a Ground Labourer.
Cutting and stacking, without removal	·045
Re-sodding	·065

REMOVING 220 YARDS LINEAL, DEPOSITING THE LOAD, AND RETURNING—PER CUBIC YARD.	Days of a Driver, Horse, and Cart.
Vegetable earth or loam	·035
Clay, sand, stony earth, &c.	·040

REMOVING EACH ADDITIONAL 220 YARDS AND RETURNING—PER CUBIC YARD.	
Vegetable earth, &c.	·020
Clay, sand, stony earth, &c.	·025

Fig. 131.

Figs. 131, 132, and 133 show the usual navvy wheelbarrow (holding about one tenth of a cube yard) most approved of as being handy

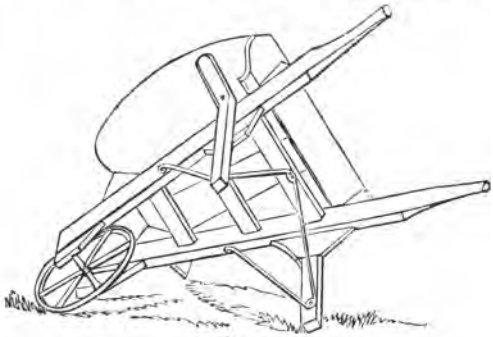


Fig. 132.

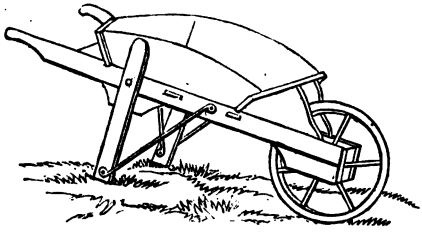


Fig. 133.

in wheeling and tilting out its contents; the wheels are mostly cast iron running in ash sockets, the strains or handles and framing generally are of ash, the sides front and back of elm, the legs are strutted with wrought iron stays in two ways, and the whole is very compact. Large numbers of this make are exported for use in making railways abroad, and we append their mode of packing for transit. It is to put the barrow beds together with the bottoms nailed in; and after making a packing case 4 feet 9 inches × 3 feet 6 inches × 1 foot 5 inches (which holds the material for six wheelbarrows) to put all the component parts of the six barrows in it, such as nails, bolts, brackets, side and other boards, &c., and wheels. On arrival at their destination the barrows can be speedily put together. If sent in this way 100 barrows would only take up 10 tons measurement, or weigh 5 tons dead weight. Earth cannot be wheeled in barrows economically to a greater distance than 100 yards. When the quantity of earth to be removed is considerable, implements holding in themselves a much greater quantity of soil are required and they are generally made to

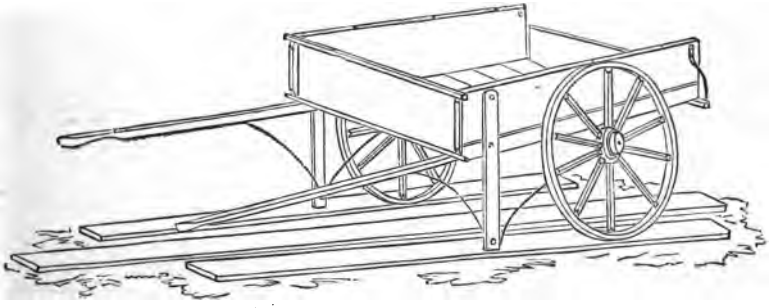


Fig. 134.

contain three quarters of a cube yard or more when drawn by horses and when no rails are used. In Fig. 134 we give view of a hand-cart very much used by contractors. With this cart incredible quantities of soil can be wheeled a long distance on a plank road and tipped over by one man; whilst at the tail end of the hand-cart are placed two rings, and in deep cuttings by the aid of a stationary steam engine with chain winch, a chain led from these two rings brings the hand-cart to the surface up a properly prepared incline with great efficiency. When once at the surface it is readily wheeled away. All contractors know the value when much earth has to be removed of using steam power for raising it at one process to its full height, as no matter how ingenious inclines may be constructed, with hand labour only the cost

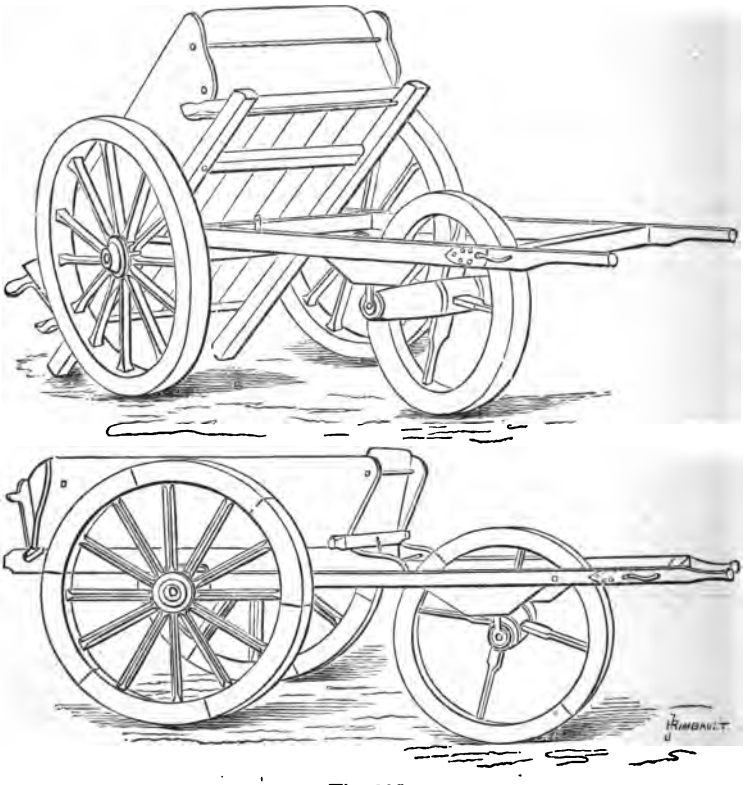


Fig. 135.

will be the same, and whenever it is possible by the aid of steam lifts whether by a direct vertical pull or by a short incline in which latter case the cart or barrow will roll up on its own wheel, the aid of steam should be called in on the score of economy. It should be remembered that although a horse run cannot be used economically for a less depth than 20 feet, steam can be made to do so, also that the vertical transport of earth is equivalent to 15 times the same horizontal distance when barrows are used and 12 times when there are horses and carts. When earth is removed up an inclined plane not exceeding 1 in 10 the extra labour entailed by each foot of rise is equivalent to removing the same load 10 feet on a level. Fig. 135 gives two views of the contractor's dobbin cart. It generally takes a full $\frac{3}{4}$ cube yard, and is a very useful tool on rough ground. The horse is attached to it by a drag chain, and the weight being on the two large wheels the handles and wheel behind it serve in the hands of the navvy as a lever to place the route of the cart in any direction he pleases. The wheels have generally 4-inch tyres, the framing being principally of ash and the body of elm. Their cost is from £12 to £13 each. In still more extensive works such as reservoirs, docks, railways, &c., the dirt

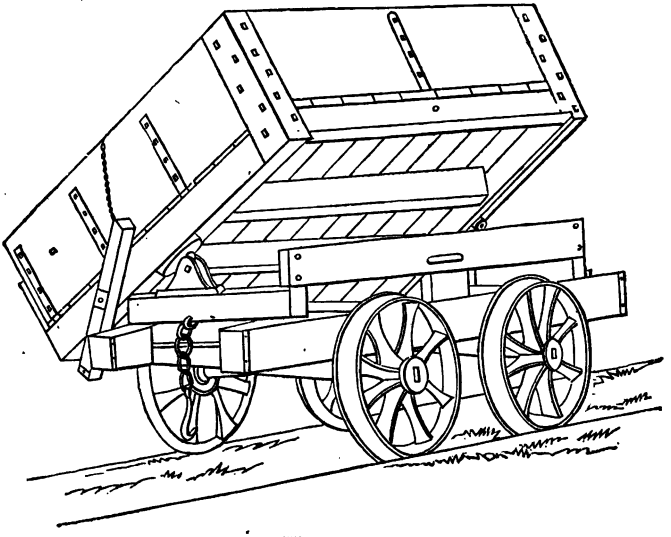


Fig. 136.

is removed in wagons running over temporary rails laid on rough sleepers, the rails being added to and advanced close to the face of the work as it proceeds. These wagons are either drawn by horses or locomotives, and are made side or end tipping. Fig. 136 represents one of the former and Fig. 137 one of the latter. They are made to

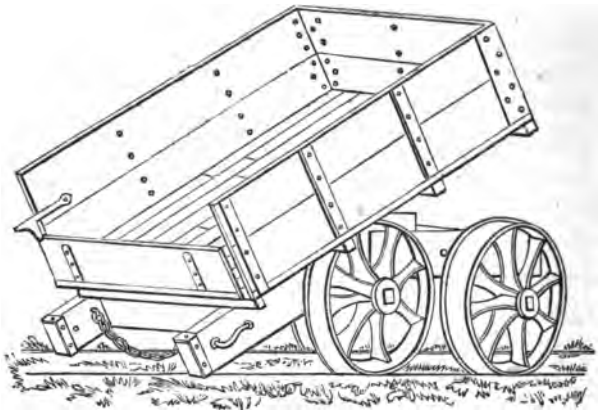


Fig. 137.

carry from 2 to 3 yards of earth each. The load is discharged from the end tip wagons by being rapidly run up to the tip where a block of wood stops further advance and the momentum is sufficient to tilt the body and discharge the contents well spread over the embankment. There are numerous systems of arranging for a ready supply of empty wagons to take the place of those filled, and often by an arrangement of inclines the weight of the filled wagons are made to draw the empty ones up; and in fact no greater amount of valuable ingenuity has been expended within the last few years than that exercised by the contractor's engineer in studying the quickest and most economical mode removing spoil from cuttings, &c. The best mode of attack, distribution of working surfaces, the notching, gulletting and undermining of them, the getting rid of the water, and the clearing away the spoil, require, on the part of those entrusted with such work, great consideration, and we strongly advise our readers living in any neighbourhood, where such operations are being carried on, to study carefully the

process in which, what for a time appears a huge chaos, is gradually reduced to order. Should land not be available for the numerous curves required in these operations, turntables such as that

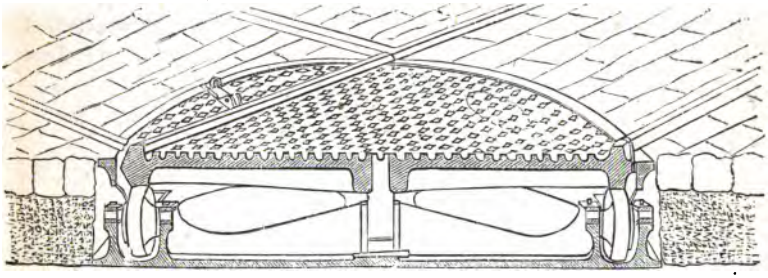


Fig. 138.

shown in Fig. 138 are most useful, and as in the kind shown the whole of the rim is one piece of cast iron, the facility for laying it down again more than repays the difference of its first cost beyond that of cheaper ones made of timbers. The wagon

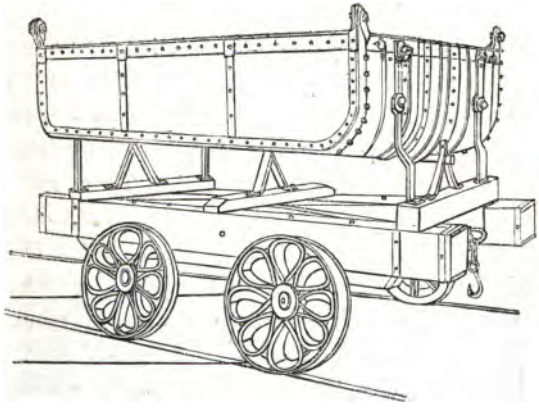


Fig. 139.

shown in Fig. 139 is shown with a wrought iron body, and, indeed, iron is often used for the bodies of dirt wagons, although the late advance in the price of this material, from the increased cost of coal and skilled labour, prevents its extension in this way. It really forms

the best material for the purpose. This particular wagon shown was specially designed to tip on either side, right or left of the line on which it runs, for the tipping of hot coke in barges from a large gas works near London. The body is supported by two props at each side, and as these are knocked aside on one hand or the other the wagon discharges it contents into shoots specially designed for the purpose and thus to the barge. They act admirably at works of this kind.

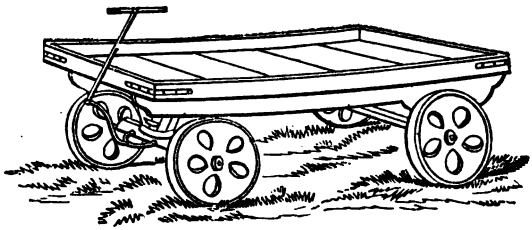


Fig. 140.

The course adopted for removing sacks, &c., and luggage generally, at stations, are by lorries similar to those shown in Figs. 140 and 141.

At the end of this work, amongst other strains, we have given the method of arriving at those to which cranes are subjected. There are a very great variety in use now, and for heavy weights, steam, or the hydraulic power, as arranged by Sir W. Armstrong, is largely used. There are so many of these instruments now in use at nearly all large towns that we do not think it necessary to describe them fully; but some of those not properly appreciated, and, to our mind, the best in use are known as the goods' shed crane, in which, by the manipulation of a rope or chain, very light or very heavy goods may be raised economically and quickly. For light goods a pull of the rope or chain on the wheel is sufficient, but in heavier goods, up to seven or even ten tons, the adjustment of this on the lower winch is necessary, and by a very simple but

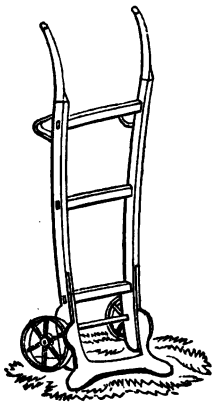


Fig. 141.

effective piece of mechanism is readily effected. Such cranes are shown in Figs. 142 and 143. The former has wood framing, and requires a stay in the roof, but the latter is of iron construction, surrounded by sufficient masonry under the platform to take the strain without any other stay.

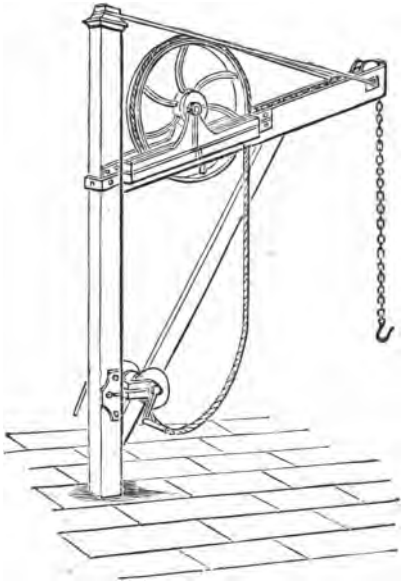


Fig. 142.

Another machine is not so well known as its merit deserves, viz., the ringing engine shown in Fig. 144. It is used for putting small sheeting piles in for wharfs, canal banks, &c. Generally, these timbers run from 8 to 10 feet long, and in section from 9 in. to 12 in. × 4 in., with a ram of about 3 cwt. attached to a rope running free over the head pulley, the rope having loose cords, one for each of the four men working it; a great number of these piles can be got in per day. Its cost varies from £12 to £15.

Fig. 145 shows the usual hand pile driver, driving piles up to 14 inches square, and any length up to 40 feet. It is generally worked by five men. In hauling up the weight by the usual crab a

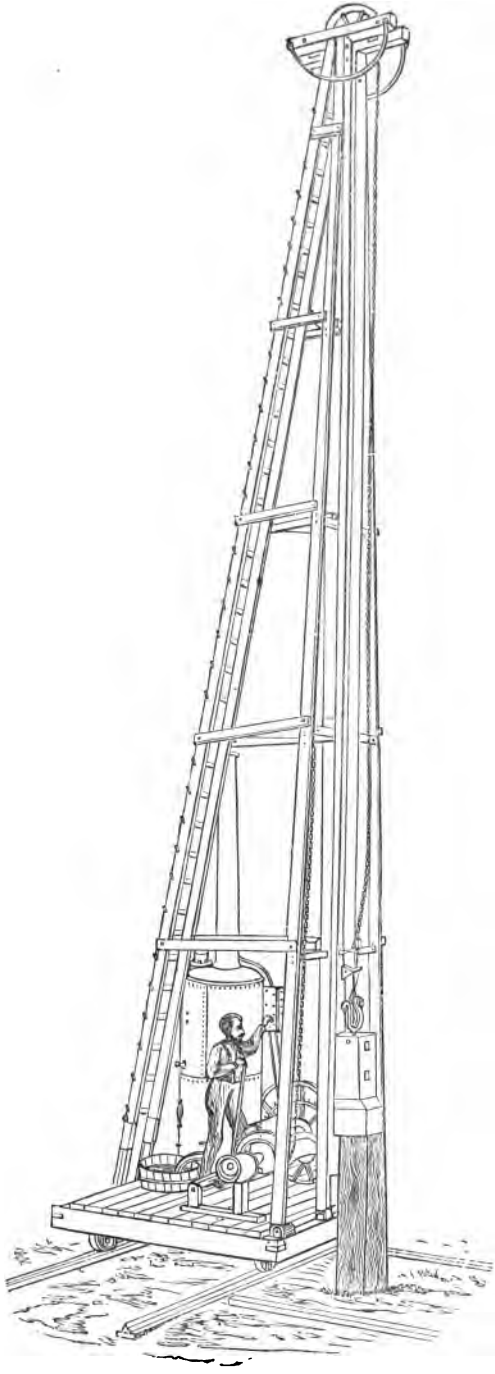


Fig. 145.

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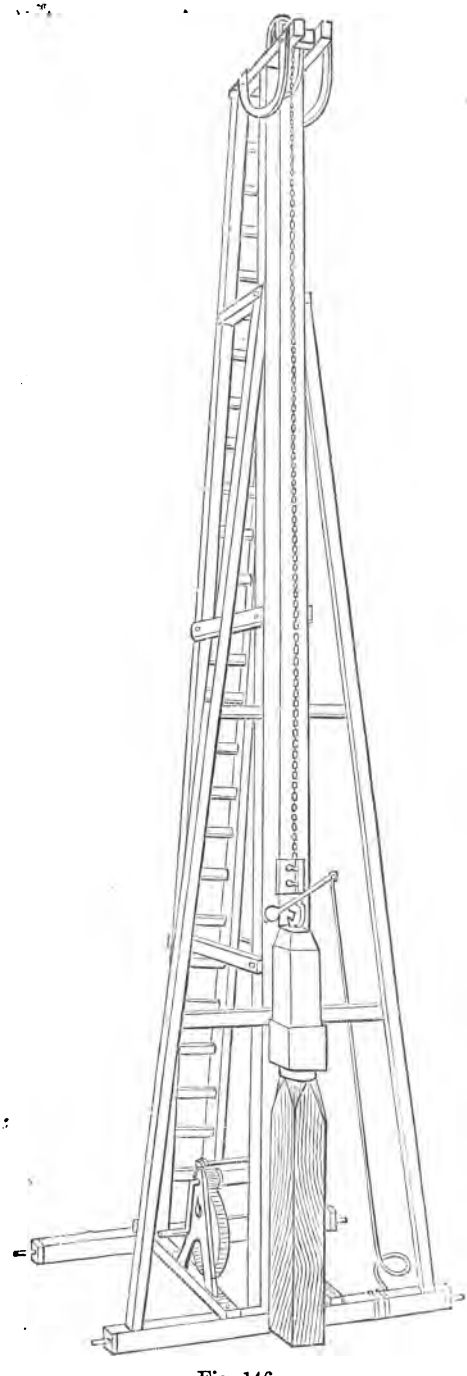


Fig. 146.

U of M

attention to the latter point. The weight which a pile will sustain is readily got from the formula

$$L = \frac{W\,H}{8\,D}$$

In which D = set of pile by the last blow in inches.
H = height the ram has fallen in inches.
L = safe load for the pile in cwts., cut off near the ground.
W = weight of ram in cwts.

Example: *What weight will a pile carry safely, the monkey weighing* 20 *cwt. and driving the pile* $\frac{3}{8}$ *of an inch with a fall of* 10 *feet?*

$$\frac{W\,H}{8\,D} = \frac{20 \times 120}{8 \times \frac{3}{8}} \quad \frac{2400}{3} = 800 \text{ cwt., or } 40 \text{ tons.}$$

CHAPTER VI.

GREENHOUSES, VINERIES, HEATING APPARATUS, ETC.

Culture of Fruit, Choice of Site, Houses lately introduced, Peach and Wall Covers, Lean-to and Span-roof Greenhouses, Melon Pits, Plant Preservers, Lawn Conservatories, Cold Frames, Heating Apparatus and Boilers.

THE increasing interest taken by all classes in the cultivation of flowers and fruits, and the comparative low cost at which in these days all kinds of structures in wood, glass, and iron can be procured, bid fair at an early date to mitigate the many disadvantages of the climate of Great Britian.

Already a great deal has been accomplished towards the culture of fruits of all kinds, and our tables are now covered with as choice a fruit raised at a moderate cost as that of any other country.

Since the introduction of orchard houses for the cultivation of vines and other fruit trees with or without artificial heat, great strides have been made with this object in view, and no modern garden, even of the highest class, furnished with all kinds of houses adopted to force vegetation, is considered complete without its orchard house. With the aid of machinery structures are now built, costing little more than the cruder houses of the class originally introduced, and any lover of gardening can now not only produce large quantities of very choice fruits, but can even raise such kinds as at one time he considered beyond his reach. Amongst the various class of structures which have

tended to develop this real source of pleasure indubitably those introduced by the late Sir Joseph Paxton (see Fig. 160) has been the foremost and most extensively patronised. Their peculiarity was that they were capable of being made perfectly secure as temporary structures, while retaining the appearance and efficiency of permanent erections, and thus they become a decided boon to annual tenants or holders of short leases.

In erecting glass houses of any kind, considerable importance attaches to the position assigned to it: if the structure is a detached one it should be sheltered from the northern winds with tall growing trees, close enough to break their force, but not so close that their branches may drip on the glass, and it should also be near an abundant supply of water, independent of what may be collected from the roof, a point especially indispensable in hot forcing houses of every description. Lean-to houses should have a south-eastern aspect whether for fruits or flowering plants, the morning sun being more strengthening and exhilarating than at any other period of the day. Span roof houses should stand north and south, with the longer elevation towards the east and west. Conservatories attached to the dwelling-house may be regulated by the position of the building or the fancy of the architect, but should be transparent or of glass on all sides, since plants grown in lean-to's can never be made handsome, seeing that they become weakly and distorted by continual stretching towards the light. Plants will not thrive without plenty of light, and must receive its direct influence by being placed near the glass, hence the extensive use of trellises of wood or iron to which the trees are trained. Trellis work is not to be recommended, however, on the back walls of lean-to's, for if the surface of the glass in the roof is sufficiently covered with foliage there is little to be gained by training on the back wall, except in the case of figs, which are found to do better in the shade. Wire is the fittest substance for trellis work, and can be procured galvanised to prevent rust. Lately great attention has been paid to this necessary art, and there are numerous manufactories supplying all the needful strainers, hold-fasts, &c., either for the internal portion of glass houses or out-door espaliers. The interior of greenhouses are generally provided with a stage in the centre and shelves round the sides on which the plants

are arranged. The angle of the centre stage for a promiscuous collection of plants should never exceed the angle of the roof, but should be a little flatter so as to admit of larger plants being placed on the upper shelves, thus giving a larger and more effective appearance from the inside. Three or four rows are sufficient, the upper shelves being about twice the width of the others. The lowest should not be less than 12 inches wide, and the rise about 8 or 9 inches. For small plants, propagating houses, &c., of course the stages may be much nearer to each other. Proper ventilation is the most important item in the management of hothouses; the builder has done his part when he has arranged for the front and a portion of the roof sashes being opened, but the gardener must use his judgment as to when and under what conditions he reduces at any time the interior temperature of the house to that of the exterior, and this forms a most important portion of his art.

As a guide, we here call the attention of our readers to a class of house, amongst the most economical yet introduced, in which good construction, arrangement, portability, and cheapness, are combined. They are adapted to all kinds of gardens, and are so constructed as to obtain the most reliable and complete system of ventilation, while they can be removed and refixed at the expiration of a tenancy without disturbing a single pane of glass. These houses are composed of lights of one uniform width, viz., 4 feet 8 inches, and are made any lengths from 8 to 16 feet; all the roofs, sides, and ends being thus constructed without rafters or framing, it leaves little or no obstruction to the light.

The system of ventilation in the roofs and sides is such that each light contains its own ventilator; and this being rendered within the thickness of the sash, ensures economy in packing or transit. The lean-to houses with side lights are constructed so that either all the front or the roof lights may be opened, or each alternate one only. For lean-to houses without front lights the ventilator is placed under the sill, in openings left for that purpose in the brickwork; the air in the latter case is thus not admitted in a direct current against the plants, but below them and immediately over the hot-water pipes, by which it is slightly tempered on entering the house. The span roof

houses are ventilated at each of the gable ends, also along the full length of ridge, and at each side.

In vineries and peach-houses the framework may rest on piers, the space between them being filled in with an embanked border. This necessitates side lights, but in many instances, when used for other purposes, no brickwork or other foundations will be required.

Figs. 147 and 148 are internal and external views of these lights adapted as peach and wall covers, no brickwork, but simply the levelling of the ground, being required. The following are the best respective internal widths and heights of these houses when erected, viz. :—

Length of Light.	Width of House in clear of Wood Sill and Wall.		Height of Back Wall covered.	
feet.	ft.	in.	ft.	in.
10	6	9	9	2
12	8	1	11	0
14	9	5	12	9
16	10	11	14	7

Figs. 149, 150, and 151 are views of the lean-to houses with side lights 4 feet 6 inches high, and for which also no brickwork is required. They form excellent greenhouses for plants, with a flat stage in front and sloping stage at back. The internal dimensions formed by the different lengths of lights used as lean-to's, when placed at the extreme angles of 25° and 40°, are as follows, when erected, viz. :—

Length of Light.	Angle.	Width in clear of Wood Sill.		Height of Back Wall covered.	
feet.		ft.	in.	ft.	in.
8	25°	7	0	7	11
	40°	5	10	9	8
10	25°	8	10	8	9
	40°	7	4	11	0
12	25°	10	7	9	8
	40°	8	11	12	2
14	25°	12	3	10	6
	40°	10	4	13	6
16	25°	14	3	11	6
	40°	11	9	14	10

For melon and pine pits with sunk pathway, as shown in Figs. 155 and 156, in the section of which we show the position of the pipes for bottom heat, the angles most in use range from 30° to 35°. The annexed table gives the various internal dimensions of lean-to's :—

Length of Light.	Angle.	Width of House in clear of Walls.		Height of back wall from Ground level.		Depth of Floor below Ground level.	
feet.		ft.	in.	ft.	in.	ft.	in.
8	26°	7	0	4	7	2	6
	35°	6	4	5	9		
10	26°	8	11	5	4	3	0
	35°	8	1	6	10		
12	26°	10	9	6	4	3	0
	35°	9	8	8	1		
14	26°	12	8	7	1	3	0
	35°	11	5	9	3		
16	26°	14	6	7	11	3	0
	35°	13	1	10	4		

When used as span roofs, as delineated in Figs. 152, 153, and 154, the width in clear of sills will be a few inches more than double the above. The eight feet houses are the cheapest and most efficient for sheltering plants and small fruit bushes in winter, and with suitable heating apparatus may be used for cucumbers and melons. The ten feet span roofs form first-class plant houses, feeders to conservatories for the growth of rhododendrons, azaleas, &c. It will be observed that these houses are a mere collection of roof and side lights, all being of the same size in width but varying in length, and for which glass is kept of uniform sizes largely in stock. They are thus supplied at a moderate cost. Manufacturers glaze them with 21oz. glass in panes 10 inches wide at about 12 per cent. extra to the prices here given.

Figs. 147 and 148 show these lights arranged as wall covers, being thus extensively used near Swansea and other towns where the atmosphere is vitiated by the fumes from smelting works, chemicals, smoke, &c. Their cost per foot run including the two ends and one door at the manufactory, divided into two classes, first for the woodwork primed, and secondly painted four coats and glazed complete with 15oz. glass in panes about 15″ × 7″, and including all gutters,

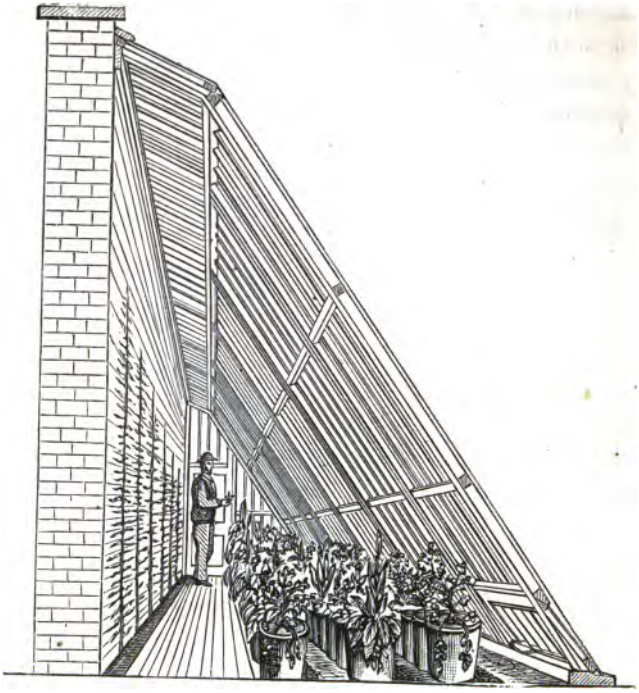


Fig. 147.

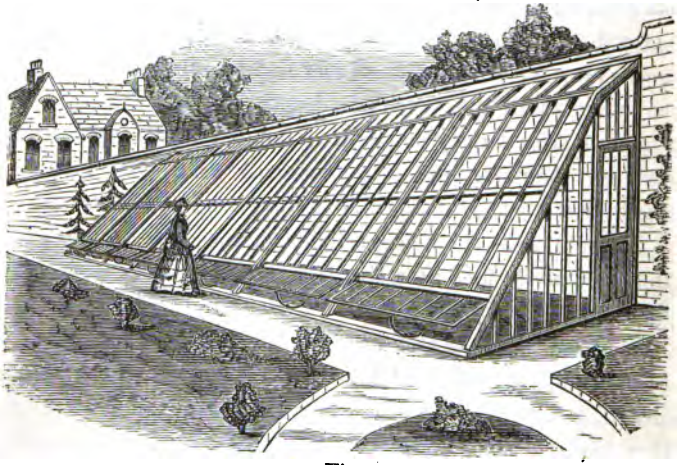


Fig. 148.

down pipes, locks, hinges; in fact, with all ironmongery complete, tie rods and columns are as follows, the cost varying considerably in proportion to the length, these being taken at 98 feet and 14 inches long respectively :—

Woodwork Primed only, but with all Ironmongery.			Wood and Glass, Painted Four Coats, with all Ironmongery.		
		s. d. s. d. per			*s. d. s. d.* per
10	feet lights.	11 9 to 16 6 foot run.	10	feet lights.	17 9 to 24 3 foot run.
12	,,	14 3 to 20 9 ,,	12	,,	21 3 to 30 9 ,,
14	,,	15 9 to 23 6 ,,	14	,,	24 3 to 36 9 ,,
16	,,	18 3 to 29 6 ,,	16	,,	28 3 to 44 3 ,,

Figs. 149, 150, and 151 show the same arranged as lean-to houses, and their cost divided into two classes as before, at the manufactory,

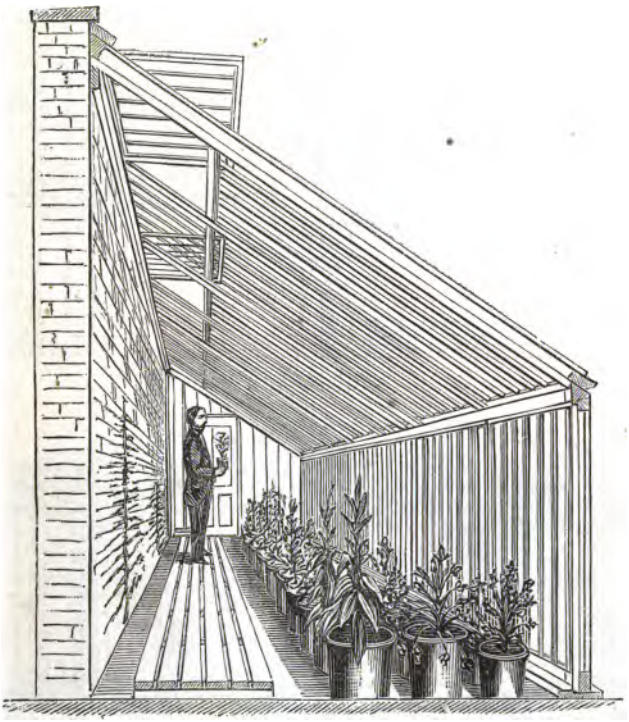


Fig. 149.

would be as follows, length of houses being still taken as 98 feet and 14 feet long respectively, viz. :—

Woodwork Primed only, but with all Ironmongery.		Wood and Glass, Painted Four Coats, with all Ironmongery.	
	s. d. s. d. per		s. d. s. d. per
8 feet lights.	11 3 to 16 9 foot run.	8 feet lights.	17 9 to 25 9 foot run.
10 ,,	14 9 to 21 6 ,,	10 ,,	22 6 to 32 6 ,,
12 ,,	18 6 to 26 9 ,,	12 ,,	27 3 to 49 6 ,,
14 ,,	22 9 to 32 0 ,,	14 ,,	32 3 to 45 3 ,,
16 ,,	27 3 to 37 3 ,,	16 ,,	38 3 to 53 9 ,,

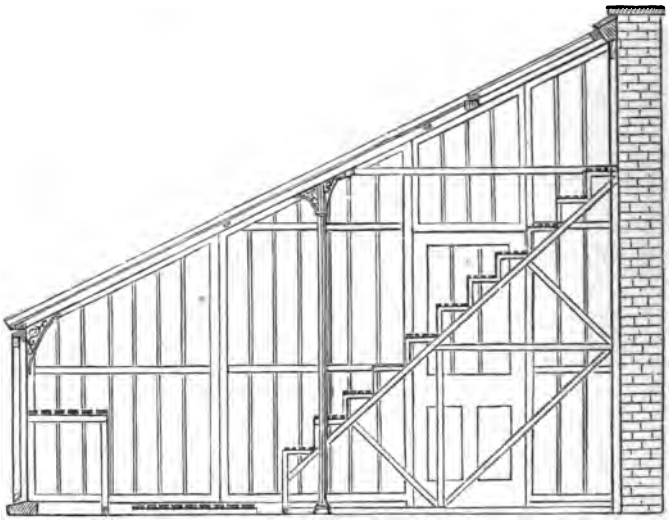


Fig. 150.

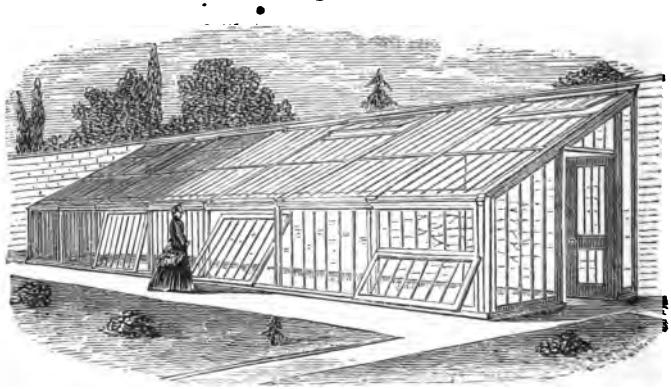


Fig. 151.

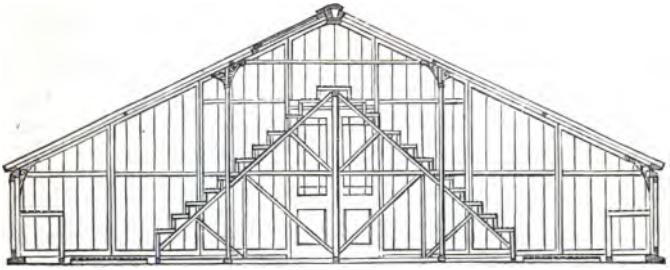


Fig. 152.

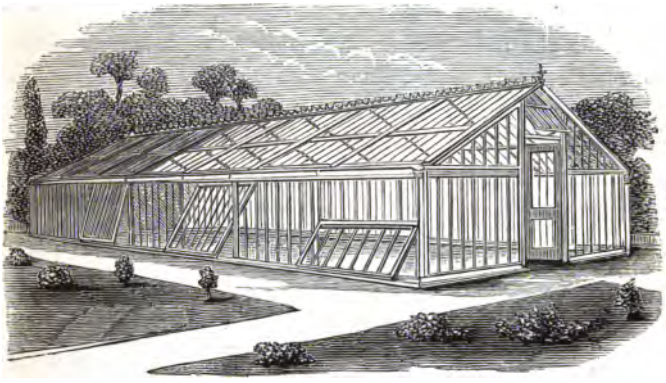


Fig. 153.

Fig. 154.

Figs. 152, 153, and 154 are views of the same kind of house arranged as span roofs, and their cost classed as before at the manufactory, the lengths being taken at 98 feet and 14 feet respectively are as follows:—

Woodwork Primed only, but with all Ironmongery.				Wood and Glass, Painted Four Coats, with all Ironmongery.			
		s. d. s. d.	per			s. d. s. d.	per
8	feet lights.	21 9 to 31 0	foot run.	8	feet lights.	35 0 to 48 9	foot run.
10	,,	28 0 to 39 9	,,	10	,,	43 0 to 60 9	,,
12	,,	35 0 to 49 3	,,	12	,,	52 3 to 74 0	,,
14	,,	42 9 to 59 9	,,	14	,,	62 3 to 89 3	,,
16	,,	51 3 to 70 0	,,	16	,,	72 3 to 103 0	,,

Figs. 155 and 156 show an arrangement of pit houses adapted to grow melons, pines, and forcing hothouse plants. In these houses there are usually arrangements for bottom heat. Their prices as lean-to's, given as before, will be as follows at the manufactory:—

Woodwork Primed only, but with all Ironmongery.				Wood and Glass, Painted Four Coats, with all Ironmongery.			
		s. d. s. d.	per			s. d. s. d.	per
8	feet lights.	8 9 to 13 3	foot run.	8	feet lights.	13 3 to 19 0	foot run.
10	,,	11 3 to 16 9	,,	10	,,	16 9 to 24 3	,,
12	,,	13 3 to 19 9	,,	12	,,	20 0 to 29 0	,,
14	,,	15 3 to 22 9	,,	14	,,	22 9 to 33 6	,,
16	,,	17 3 to 25 0	,,	16	,,	26 0 to 38 0	,,

Fig. 155.

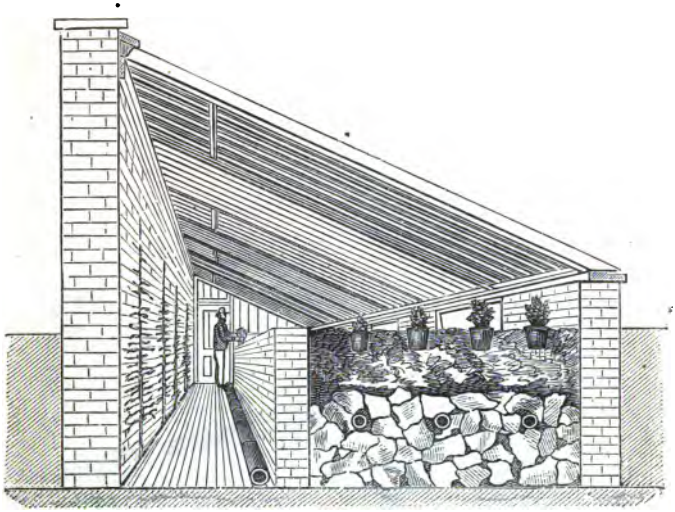


Fig. 156.

As span roofs their prices would be as follows :—

Woodwork Primed only, but with all Ironmongery.			Wood and Glass Painted Four Coats, with all Ironmongery.		
		s. d. s. d. per			s. d. s. d. per
8	feet lights.	16 9 to 25 3 foot run.	8	feet lights.	26 0 to 35 9 foot run.
10	,,	22 6 to 33 3 ,,	10	,,	34 0 to 48 3 ,,
12	,,	28 9 to 42 0 ,,	12	,,	42 6 to 60 6 ,,
14	,,	35 9 to 50 9 ,,	14	,,	52 0 to 73 3 ,,
16	,,	42 9 to 59 3 ,,	16	,,	61 9 to 85 9 ,,

These buildings can be heated for all purposes, the best mode being by hot water, but flues or any other system may be applied in the same manner as in other glass houses, and they are also often used without artificial heat. They make good greenhouses, conservatories, vineries, orchard and peach houses, pineries, wall covers, stoves, cucumber, melon houses, &c. Fitted up and glazed complete with the utmost care before leaving the manufactory, every screw hole being made and each part numbered, there is no difficultyexperienced in refixing them by persons previously unacquainted with their construction.

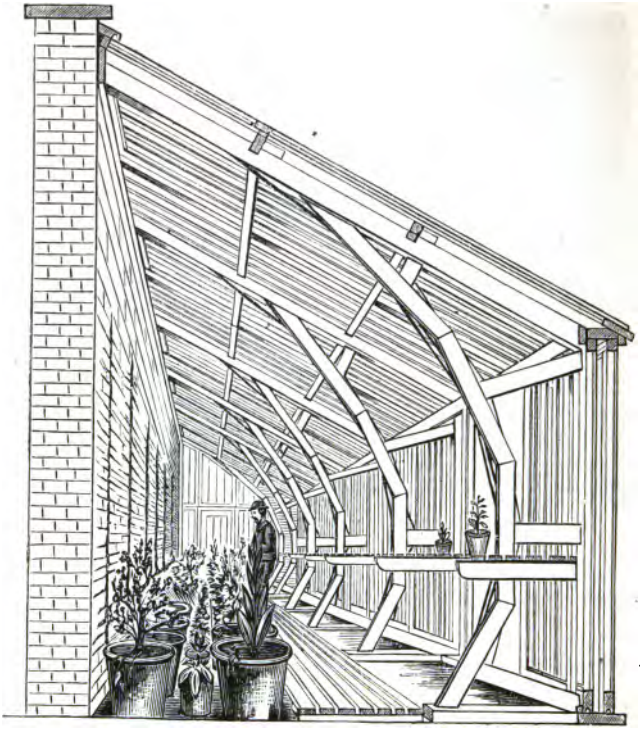


Fig. 157.

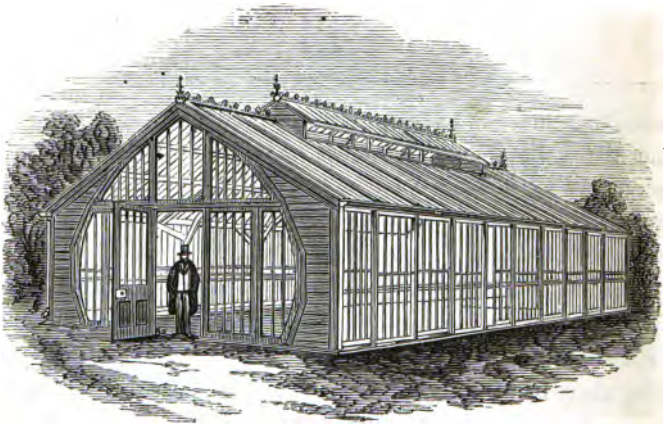


Fig. 158.

Figs. 157 and 158 are views of houses specially designed for tall plants in the case of span roofs and as lean-to's to relieve the back wall from any pressure due to the weight of the roof. These are useful in many cases where old walls exist and where taking down and rebuilding the same would be too expensive. The whole of the weight of the roof is thrown upon the feet of the principals, placed about 10 feet apart, and the roof is simply formed of 2 inch lights placed upon purlins. The centre of the span roof houses of this kind are made, and really look extremely light.

Fig. 159.

Fig. 160.

Fig. 159 gives sketch of the usual lean-to greenhouse with rafters, and the Paxton roof hothouse is shown in Fig. 160. We prefer in all cases wood framing to iron for hothouses, since the contraction and expansion of both wrought and cast iron and glass differ so widely under the circumstances as to render it a matter of impossibility to keep the buildings watertight.

There has also been lately introduced an assortment of garden frames, called plant preservers, suitable for all purposes to which frames and lights can be applied.

Fig. 161 shows one with wood sides, admirably adapted for ground vineries, early peas, salads, strawberries, &c. The plants are easily attended to and watered without the trouble of shifting loose glass,

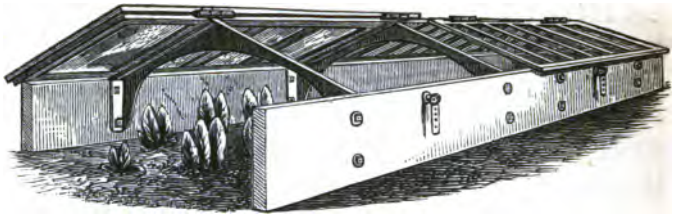


Fig. 161.

and either open or closed, the lights are securely fixed by the set opes supplied to each light. To open all the lights on one side all that it is necessary to do is first to lift the lights and to let them rest on the set opes, then from the other side rest the left hand on the ridge, lean forward and raise the light by the right hand, and bring it over the opposite light as shown. Half the pit is thus exposed for ventilation and attending to the plants. Anything that can be grown in hand glasses, pits, and frames of any description can be grown in these plant preservers. We give in the subjoined list the sizes and prices kept in stock, and these will suit all places they may be required for.

The cost of these with wood sides, complete, painted three coats, and glazed with 21 oz. glass, 12 inches wide, are as follows, with one pair of ends :—

	s. d. *s. d.*		*s. d.*
2 feet wide.	9 6 to 10 0 per foot run.	5 feet wide.	16 6 per foot run.
3 ,,	12 3 to 13 3 ,,	6 ,,	16 9 ,,
4 ,,	14 0 to 15 3 ,,		

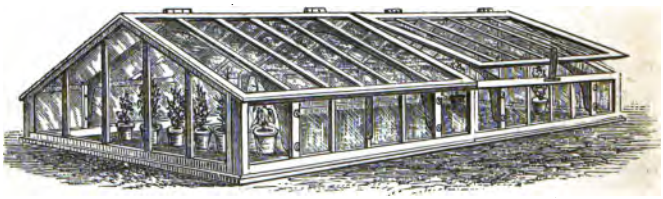


Fig. 162.

Another useful and ornamental appliance for the amateur gardener is the lawn conservatory shown in Fig. 162, similar in construction to the plant preservers, but having glass sides ; the sizes usually kept in

stock are made 12 feet long, complete, with two ends, all painted and glazed, and the prices are as follows:—

			s. d.
4 feet wide.	1′ 6″ high at sides.	2′ 6″ at ridge.	15 6 per foot run.
5 ,,	,, ,,	3′ 0″ ,,	18 3 ,,
6 ,,	,, ,,	3′ 3″ ,,	21 0 ,,

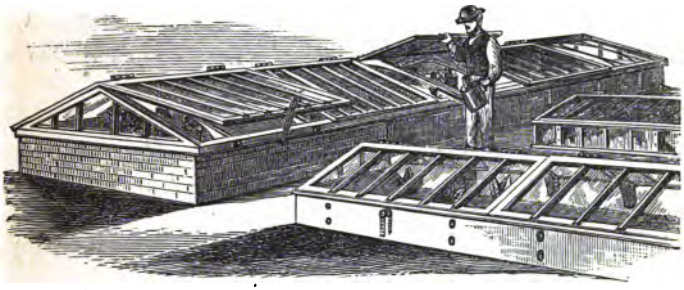


Fig. 163.

Fig. 163 shows, amongst the rest, the same kind of framework and sashes arranged as a forcing pit with brick walls, the latter usually being 4½ inches thick; the sizes and prices kept in stock form the three widths given, and the prices are as follows, painted and glazed, complete with glass ends (brickwork not included):—

Width of pit ft. in.	s. d.
5 0	13 0 per foot run.
6 0	15 6 ,,
7 6	18 9 ,,

Any length of pit can be made that are multiples of 4′ 0″, that being the width of each light, from 12′ 0″ to 72′ 0″ or more.

Fig. 164 represents the well-known ordinary melon or cucumber pit frame, the sides are usually dry red deal 1¾ inches thick, the height at back being 24 inches, and in front 13 inches, with mullions between each light. The usual lengths kept in stock are multiples of 4 feet, and the widths mostly 6 feet, both dimensions being clear of frame. The prices given below are arranged so as to show value of

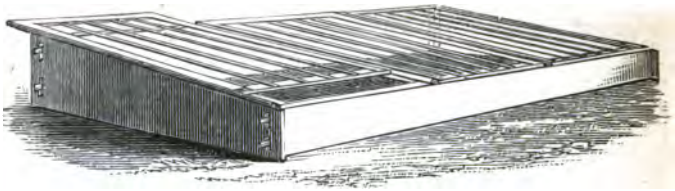


Fig. 164.

woodwork only primed as before, and also for the work painted and glazed complete :—

	Primed only.		Painted & Glazed.		
	s.	*d.*	*s.*	*d.*	
Covering 24′ 0″ super of soil	1	5	2	0	per foot super.
,, 72′ 0″ ,,	0	10	1	6	,,
,, 144′ 0″ ,,	0	8	1	4	,,

The larger the size of pit adopted, therefore, the cheaper the covering becomes.

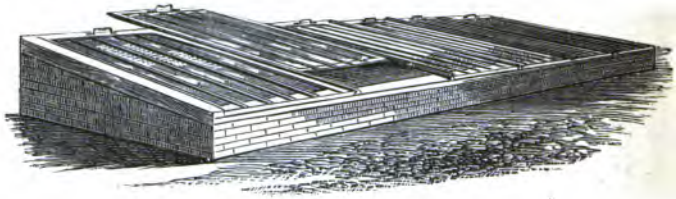


Fig. 165.

A cheaper arrangement still of forcing pit, cold frame, and cucumber pit, by using wood sills and lights on brick walls is shown in Fig. 165; these are usually kept in stock to fit walls 6 feet wide in the clear, and the prices (not including brickwork) are as follows :—Areas covered being given about 8d. per foot super of ground covered for woodwork primed only, and 1s. 3d. per foot super when painted and glazed, irrespective of size.

As stated before, the best system of heating artificially houses of all kinds, is by means of hot water piping, and from a long list of boilers, we prefer that known as the Patent Double L Saddle Boiler (shown in Fig. 166), which possesses all the advantages of the old saddle boiler, with the following improvements, viz. :—The water

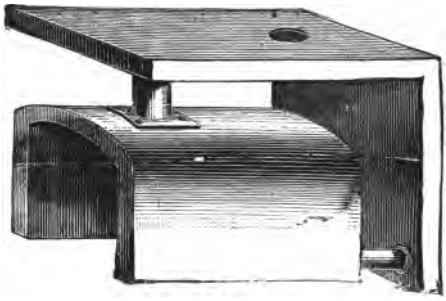


Fig. 166.

space at the back and over top of saddle increases the heating surface to such an extent that it will do nearly double the amount of work with the same quantity of fuel. The cost of setting is also considerably reduced, and likewise the space occupied. They are simple in construction, and being made of wrought iron are not liable to crack. In span roof orchard houses and vineries, to promote the growth of wood, two pipes are placed along each side, as shown in Fig. 160, which represents the late Sir Joseph Paxton's principle of erecting hothouses.

In order to give a rough idea of the usual arrangement of hot-water apparatus, we append a few cuts.

Fig. 167 shows two 4-inch pipes along one end and front of a lean-

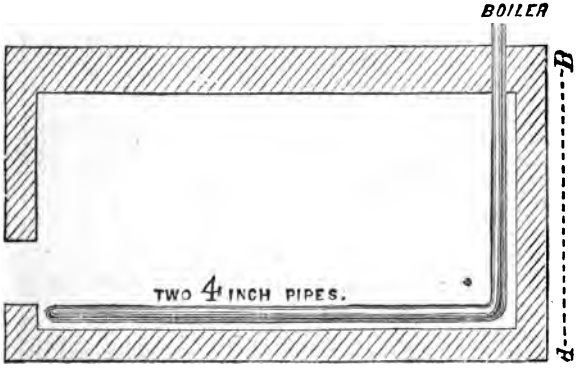
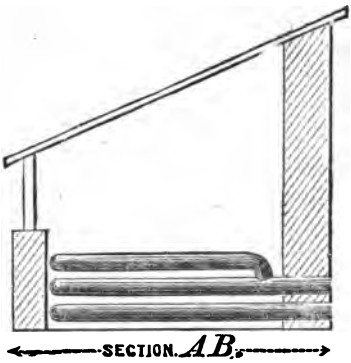


Fig. 167.

to house, which will be found very suitable for the kind of greenhouses shown in Figs. 149, 150, and 151.

Figs. 168 and 169 give No. 3 4-inch pipes for additional heat.

Fig. 168.



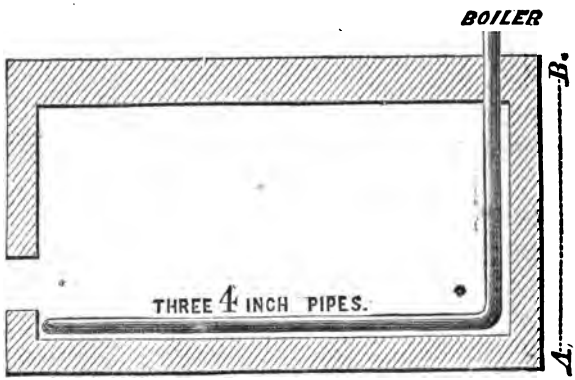
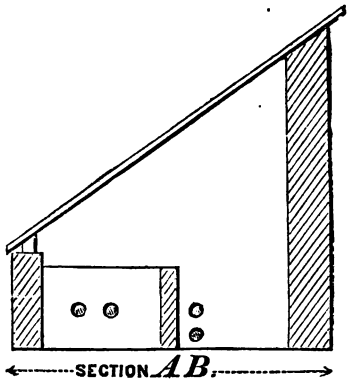


Fig. 169.

Figs. 170 and 171 give an arrangement of pipes suitable for the forcing pits shown in Figs. 155 and 156.

As the situation of the boiler, the extent of piping, and the number of shut-off valves required in each house are seldom or ever the same,

Fig. 170.



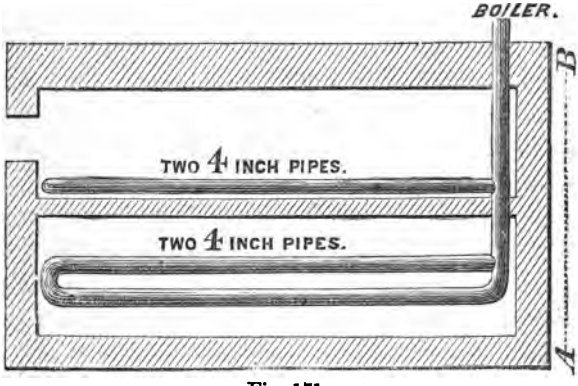


Fig. 171.

we are unable to give a general rule for the cost, and this is best ascertained from any of those firms who make this a matter of study, and of whom there are many throughout the country.

CHAPTER VII.

USEFUL TEMPORARY STRUCTURES.

Emigrants' Huts, Miners' Cottages, Workmen's Barracks, Farm Buildings, Warehouses, Cricket Pavilions, Churches and Schools, Drill Sheds, &c.

EMIGRANTS' OR WORKMEN'S HUTS.

FIG. 172 shows an elevation, and Fig. 173 the ground plan of a hut suitable for temporarily housing men on large works, or for the use of emigrants. It is built wholly of wood and packs in a small compass on board ship. The size is generally 24 feet by 16 feet on ground level, and the height is 7 feet to eaves. There are two partitions running across the hut the same height as the eaves, thus dividing it into three compartments, the centre one for living in generally and taking meals in, and the two others for bed-rooms. Large numbers of these have been taken out by emigrants, and the size and construction are somewhat as adopted by the authorities at the War Office for the use of their army at the Crimea. The framing throughout is of good red deal 3″ thick, the floor 1 inch, the roof and sides are covered with $\frac{3}{4}$ inch weather boarding and as an extra precaution the roof should have felt sufficient to cover it sent with it. Contractors taking in hand large works abroad with these huts are able to house their men immediately on their embarking. In very hot climates it is advisable to have an additional skeleton roof on posts to take the first heat of the sun, and by doing this a verandah all round can easily be formed at the same time. The cost of the hut as shown in the engraving would be about £40. Still more portable buildings of this class are made, but invariably the cost becomes much greater and the arrangement of buildings shown has been repeatedly proved to be the completest and cheapest of its kind.

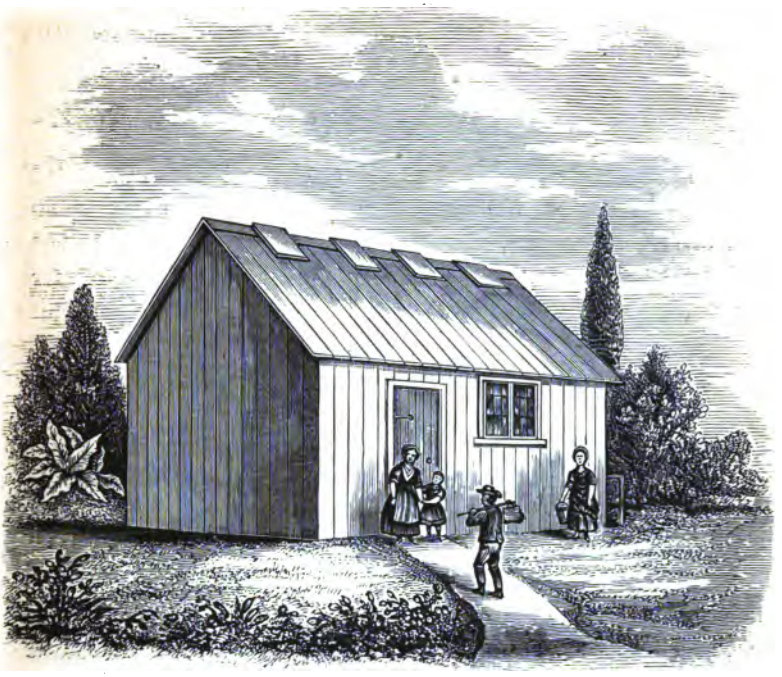


Fig. 172.

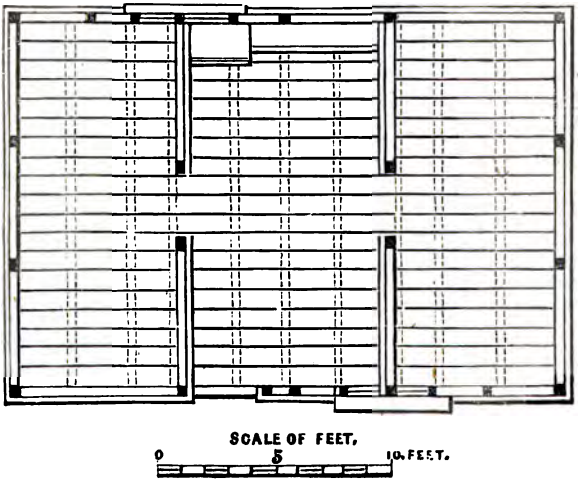
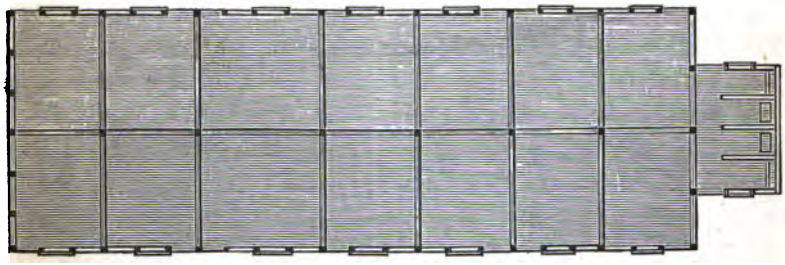


Fig. 173.

WORKMEN'S BARRACKS.

FIG. 174 is an elevation, and Fig. 175 a ground plan of wooden buildings for housing workmen. The space covered 90 feet × 30 feet divided into fourteen separate rooms, allows 12 feet × 15 feet each for 12 men, and two larger rooms, each 16 feet × 15 feet, for the foreman and offices. With the cross partitions taken out, this building makes a very useful temporary hospital for towns where an outbreak of any contagious kind occurs unexpectedly. Closets and urinals are provided in a small lean-to at one end, to which proper drains in all cases should be laid. It is generally lined throughout and ceiled, a clear space being left between the ceiling and the roof proper the full length of the building for ventilation, and a hinged ventilator is provided, opening into this from each compartment, while louvred gables are inserted at each extreme end. The sides are formed of 4 inch timbers boarded outside with $\frac{3}{4}$ inch weather boarding, and lined with $\frac{1}{2}$ inch match board. The windows when used as an hospital are hinged at the base of the top sash and fall inwards, as barracks. The rooms are lighted by ordinary casements and frames. The floor is 1 inch thick laid on $4\frac{1}{2}$ inch × 3 inch joists, resting on longitudinal sleepers placed 5 feet apart. The floor should be kept well off the ground, and if a brick dwarf wall is inserted under the sills sufficient air bricks should be inserted as will secure a through current of air underneath the joists. In a plain building of this kind corrugated zinc or iron is to be preferred to felt for the roof as being more durable and less liable to leakage. The costs of these quarters complete is about from £385 to £420, and if well looked after they will last 15 or 20 years. As barracks, workmen readily pay a good rent for their use, and at the expiration of the time named the building may be in a saleable condition.

Fig. 174.



SCALE OF FEET.

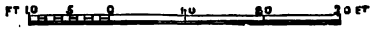


Fig. 175.

COTTAGES FOR MINERS, ETC.

THE class of building shown in Fig. 176, and of which Fig. 177 gives a ground plan, is adopted for the housing of miners or other workmen and their families in hilly, and out-of-the-way districts, or wherever more substantial materials than timber is not readily procurable, and again when time will not allow of stone or brick buildings being erected. There are large numbers of them in South Wales let to the workmen by the colliery and ironwork proprietors at a weekly rent. The whole of the work is of timber, with the exception of the cross partitions occurring every 44 feet, which is generally of rough rubble, or otherwise of brickwork, and in this the fire-places for cooking, &c., are placed. The space covered by each cottage is 22 feet long by 23 feet wide, divided into a living room or kitchen 23 feet × 13 feet, and two bed-rooms each 11 feet by 8 feet, with a pantry attached as a lean-to about 6 feet × 4 feet. The sides of the cottage are 9 feet high. Occasionally the partition dividing the bed-rooms is extended to the cross wall, thus reducing the kitchen to 13 feet × 11 feet, and giving an additional front room of the same dimensions. A rough rubble dwarf wall is put in under the sills, and often the kitchen, living-room, and pantry is paved, the bed-rooms only having wood floors. The sides are composed of 3 inch framing, with $\frac{3}{4}$ in. outside boarding, and $\frac{1}{2}$ in. side lining, with which also the roof is generally ceiled throughout, and hinged ventilators placed in each bed-room. The roof is covered outside with slates, and when built in blocks of 6 or 10, they have a very good appearance, and if the work is placed in good hands, the latter number can be erected within 6 weeks. The outside of the work receives three coats of good oil colour and the interior is sized, stained and varnished. Their cost runs from £95 to £100 per cottage fixed complete, but this depends in a great measure upon the accessibility of the site on which they are built, and as they are only adopted in out-of-the-way districts this item requires attention.

Fig. 176.

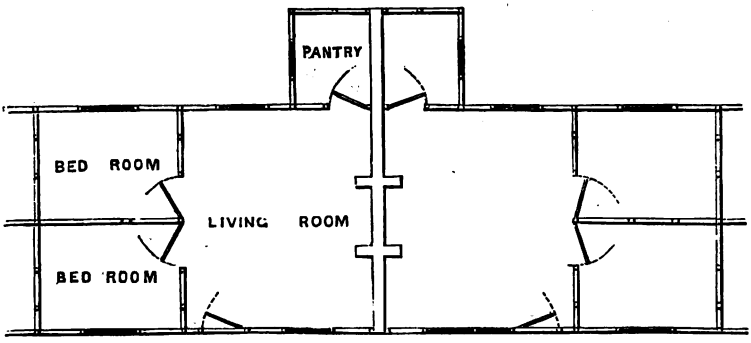


Fig. 177.

CONTRACTOR'S OFFICE.

THE building shown in Fig. 178, and of which Fig. 179 is a ground plan, is designed to form a temporary office for the use of contractors or others carrying out large works of any kind; having accommodation under the one roof for the continual residence of the time-keeper or other person in charge of the work. The advantage of such a building is that it can be bought and erected at very short notice, and that it enables the contractor to have his interests attended to immediately the work is commenced. There have been numbers of these built on this pattern throughout the country giving universally great satisfaction. The only stone or brickwork needed beyond a dwarf wall for the sills to rest on are the three chimney stacks and their respective hearths. The size of the building shown is 33 feet by 34 feet; and it is 10 feet high to the eaves, the lean-to forming the back kitchen is 15 feet by 8 feet. The lobby, kitchen, and scullery are generally paved either with stone or brick on edge, and the three other rooms have wood floors. The outside framing is 3 inches thick, with $\frac{3}{4}$ inch outside boarding, and the whole building is lined and ceiled with $\frac{1}{2}$ inch lining. The roof is covered with slate, the rafters being $3'' \times 2''$ placed 15 inches apart from centre to centre. The outside receives three coats of oil colour and the interior is sized, stained and varnished. Its cost, exclusive of brickwork or masonry erected complete, is about £150, for which sum ample accommodation is given for a contractor's private business room, the assistants, &c, having besides a room separate, and devoted to their own use. In addition, a person can always be resident on the works, and in wild districts provisions can be stored for use when required.

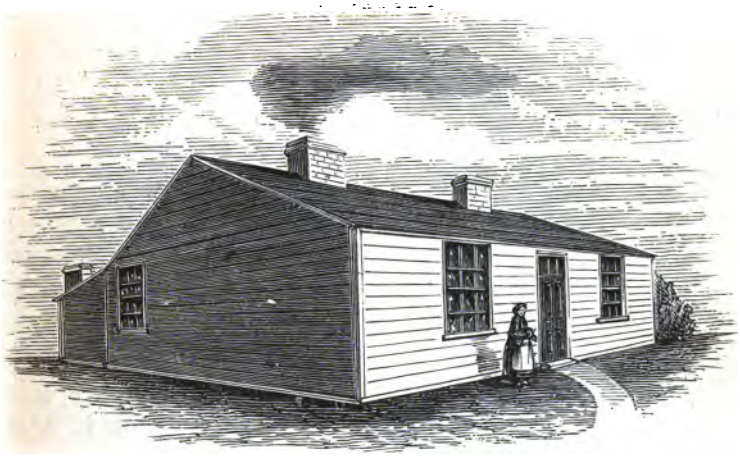


Fig. 178.

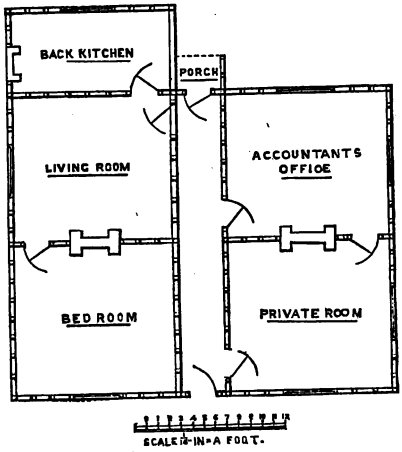


Fig. 179.

BARN AND GRANARY.

THE woodcuts given as Figs. 180 and 181 represent a two-storied building, the top floor being used as a granary. This is a very necessary adjunct of a farmstead, and is constructed in the most substantial manner to sustain the greatest weight which can be stored in the top floor. Structures of two floors are not always desirable in timber, but where the load is stationary as in this case, it may be adopted with perfect satisfaction. The corner posts are 7″ × 7″, door posts 5⅛″ × 4″, and intermediate posts 5½″ × 2½″, well-braced with diagonals 4½″ × 3″. It is not lined, and is covered on the exterior with ¾″ weather boarding. The roof is either slated or covered with corrugated iron or zinc, but the first, viz., slating is to be preferred. Tiling of any kind makes also a very durable covering, but requires stronger framing than we have allowed for in the sum named below. The building is represented as being 50 feet long by 20 feet wide, the height from ground floor to upper floor being 11 feet, and from ground floor to eaves 16 feet. The joists of ground floor are 4½″ × 3″ on sleeper joists placed 5 feet apart on which is laid a floor one inch thick, iron-tongued, and the upper floor is composed of 9″ × 3″ joists laid 15 inch centre to centre, braced twice with herring-bone strutting and covered same as ground floor. The sills of the building are laid on bricks or stonework, and in each case air bricks are inserted to ensure a good current passing under the joists. The cost of such a building erected complete is about £235 painted three coats oil colour.

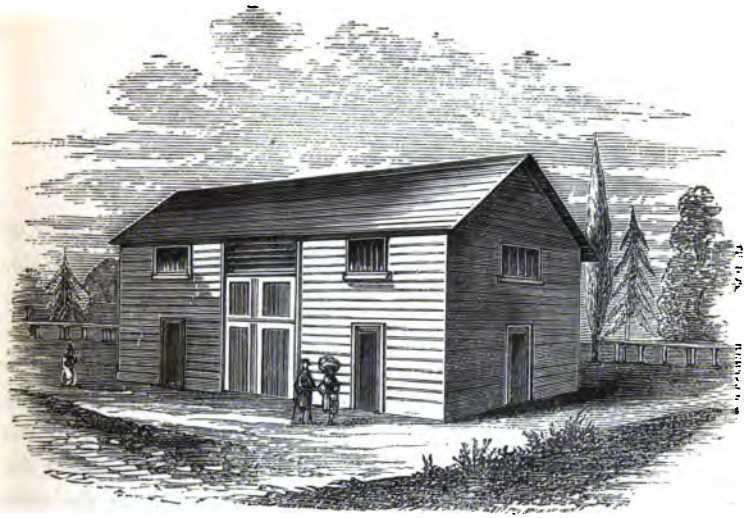
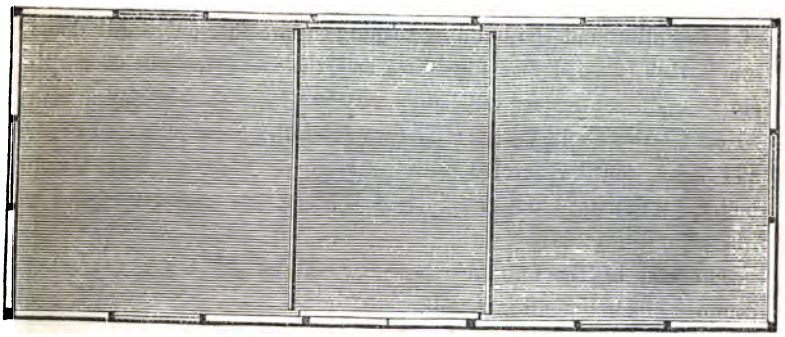


Fig. 180.



SCALE OF FEET.

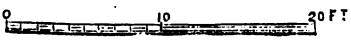


Fig 181.

STOREHOUSE.

FIGS. 182 and 183 show the elevation and plan of a warehouse or stores. It is represented as being 60 feet long and 30 feet wide, containing a lock-up stores the full length of the building by 15 feet wide; two smaller ones, either of which may be used as offices, 15 feet long by 10 feet wide, and a covered space for keeping goods in the dry, of about 40 feet by 15 feet. The general arrangement is very good for such buildings, as they are generally erected close to the water in canals or docks, or it serves equally well as a good shed for railways. It is either constructed entirely of timber, or the main columns are of iron, simply filled in with wood framing. The sides are 12 feet high, the floor 1¼″ thick, tongued with hoop iron laid on proper joists, and it is ceiled only in the enclosed spaces; light and ventilation being given immediately under the eaves, the projection of 5 feet all round the building keeping the weather out. All doors are 2 inch, framed and filled in; and the windows, part of which are hung on centres for ventilation, are two inches thick, glazed with 21 oz. Hartley's rolled plate. The whole of the exterior, both in roof and sides, can be covered with boarding or with corrugated iron bolted to the wood transoms placed between the timber uprights or iron columns.

The cost of the building shown would be about £450, erected complete, including all materials.

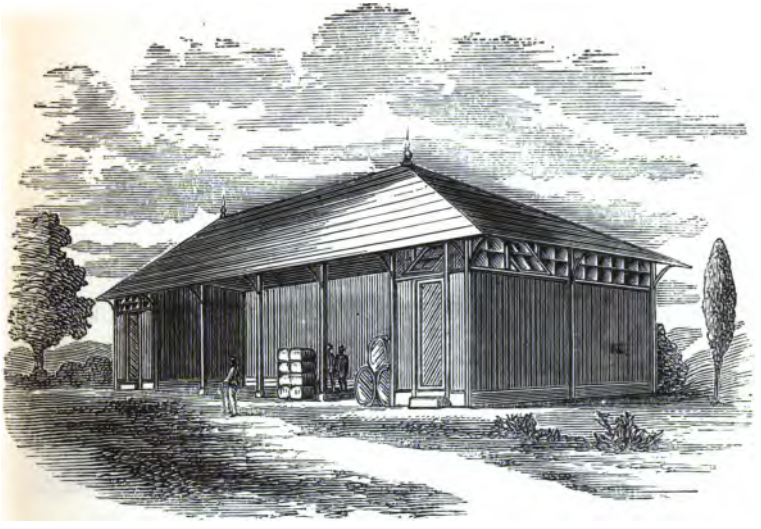
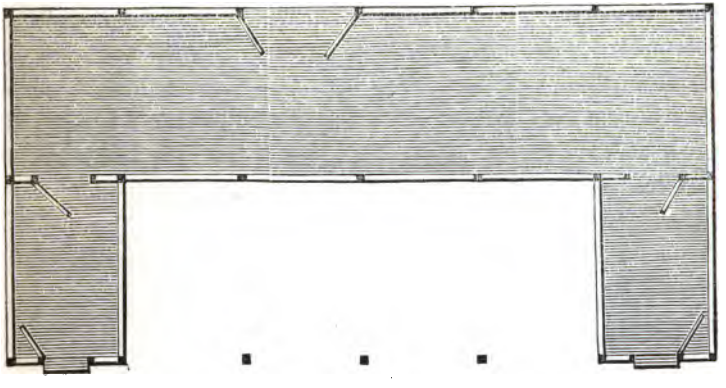


Fig. 182.



SCALE 1/16 INCH = 1 FOOT.

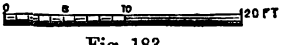


Fig. 183.

CRICKET PAVILION.

THE cricket pavilion shown in Fig. 184, and of which Fig. 185 is a ground plan, is designed as suitable only for the temporary use of junior clubs, being only 30 feet long by 20 feet wide and 9 feet high to eaves. It is, however, well lighted and furnished with refreshment bar, a seat being placed all round the inside of the building, the under portion of which is divided into lockers for stowing away the implements used in the game.

The front has a sloping stage for the use of lookers on, and the roof projecting over this affords shade and shelter, this projection being also carried slightly round the whole of the building. The sides are composed of 3 inch framing, covered with $\frac{3}{4}$ inch weather boarding, painted three coats good oil colour. The roof is best slated, and the whole of the interior is lined throughout with $\frac{1}{2}$ inch matched boarding well stained and varnished. The flooring is 1 inch thick, laid on strong joisting; the doors are $1\frac{1}{2}''$, four panelled, properly hung; and the windows are 2 inch, glazed 21 oz. clear sheet. Its cost is about £130, erected complete, including all materials.

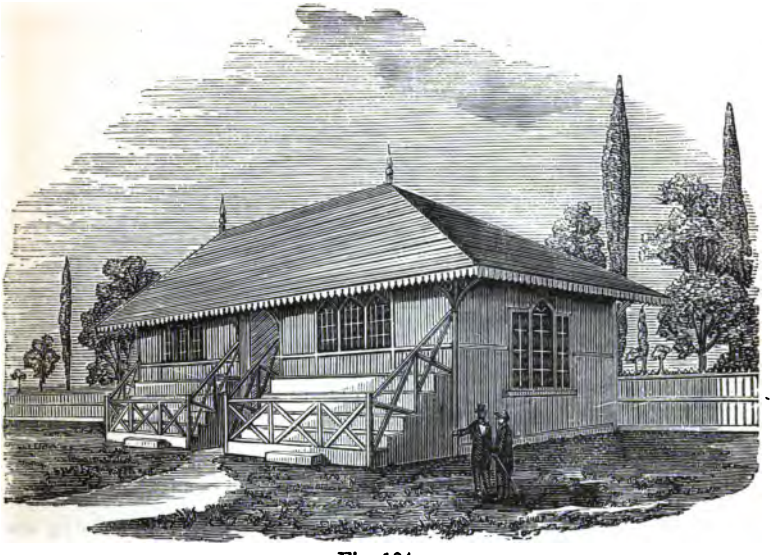


Fig. 184.

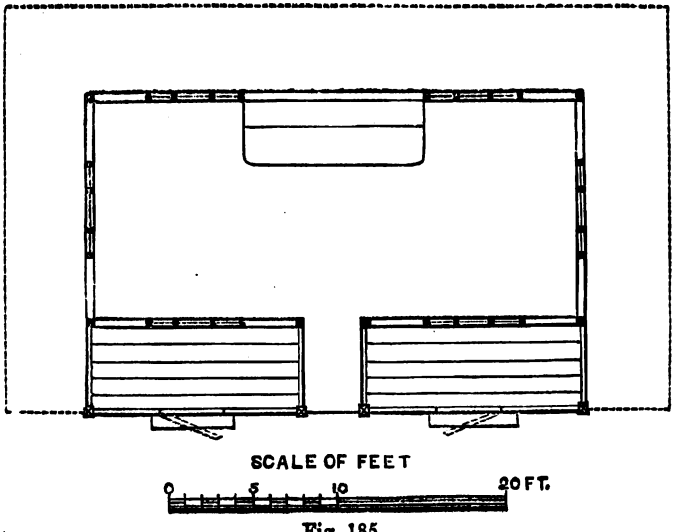


Fig. 185.

CRICKET PAVILION.

FIGS. 186 and 187 represent the elevation and ground plan respectively of a similar cricket pavilion, but much larger than the last example, being 40 feet long by 23 feet in the clear, and 10 feet high to the eaves. It is surrounded by a verandah 6 feet wide on three sides, supported by cast iron brackets carried by the main building. The interior is fitted up with refreshment counter and stores on one side of same, and on other side a dressing-room. Seats with lockers in are provided all round as before. The main building is lighted altogether from the front, the sashes being hinged at the top; by this means the whole of the pavilion can be used as a smoking lounge and thrown open to the field. The refreshment-room, stores, and dressing-room are lighted from the back. The framing is all 4 inches thick, covered with $\frac{3}{4}$ inch weather boarding, and the inside lined throughout; the partitions being simply 1″ matched boarding with suitable ledges. All the doors are $1\frac{3}{4}$ inch four panel, and sashes 2 inch glazed 21 oz. glass. The roof is best when slated, and those which have been erected on this plan give general satisfaction. Painted three coats good oil colour outside, and stained and varnished inside, erected complete with all fittings, its cost is about £315.

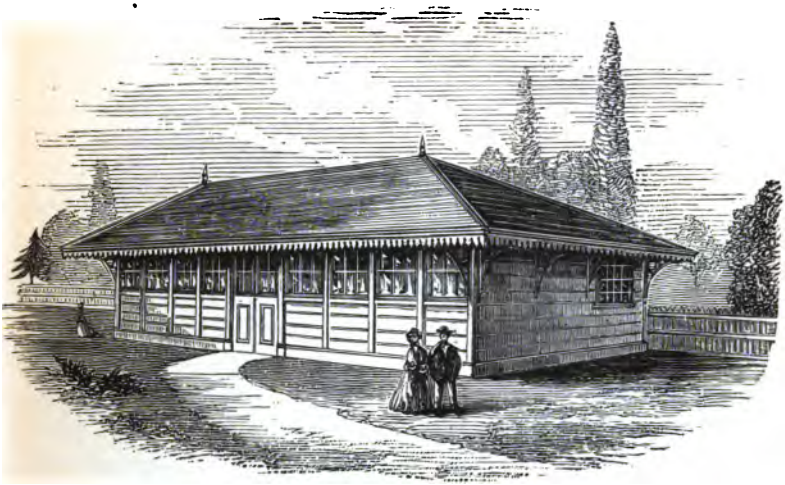


Fig. 186.

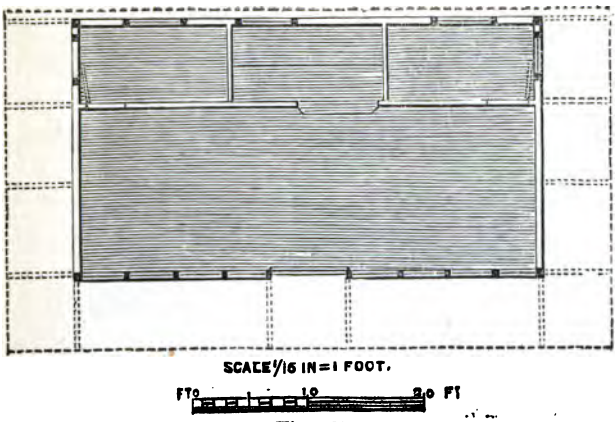


Fig. 187.

INFANTS' SCHOOL-ROOM.

FIG. 188 shows the elevation and Fig. 189 the ground plan of a village schoolroom, and as it is only for temporary use, forming simply the beginning of a more advanced class of building, it is constructed of wood throughout, as being the most inexpensive. The one shown is 25 feet long by 16 feet wide over all, and 9 feet high at the eaves. At oneend a lean-to is supplied, forming closet and cloak room, fitted with pegs for keeping each scholar's clothes separate. This size will accommodate fifty children, and the utmost care is taken to secure proper ventilation. The framing is 3 inches thick, covered on the sides and ends with $\frac{3}{4}$ inch weather boarding, the roof being slated. Such a building, painted three coats good oil colour outside, the inner surface being stained and varnished, would cost from £80 to £90, erected complete and fit for occupation.

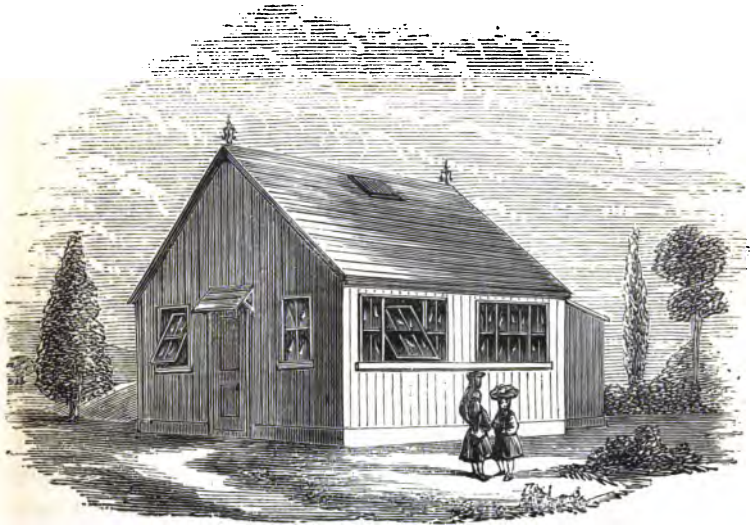


Fig. 188.

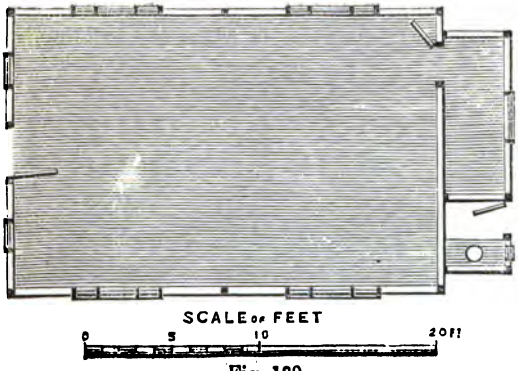


Fig. 189.

SCHOOL-ROOM.

FIGS. 190 and 191 give the elevation and plan of a school-room of a somewhat more pretentious character, and capable of accommodating eighty children, being 30 feet by 17 feet, with porch, closet and cloak room as before, but on a larger scale. The sides are 11 feet high, with a slated roof, and the inside of the building is ceiled, while dormer louvring is so arranged that a current of air passes through the two gables as well as the sides of the roof as shown. This amply provides for thorough ventilation. The whole is constructed of 4 inch framing covered with $\frac{3}{4}$ inch weather boarding, while the floor is 1 inch thick, secured to proper joisting. The doors are $1\frac{3}{4}''$ thick, the windows all 2″, the top portion of the latter swinging on centres The cost of such a structure would be from £150 to £160, erected complete, fit for occupation. The outside covering may be of corrugated iron or zinc, but we consider timber construction better, neater, and more suitable for the purpose for which the building is designed.

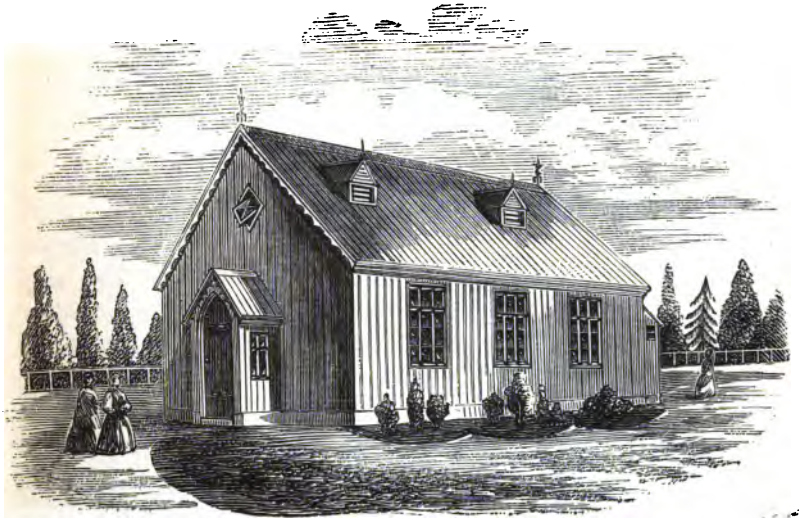


Fig. 190.

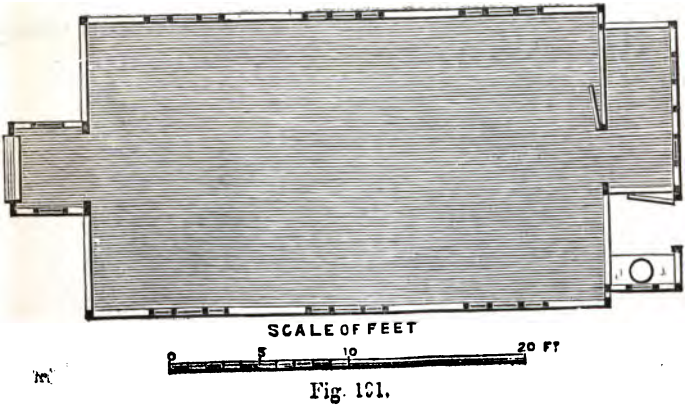


Fig. 191.

SCHOOL-ROOM.

ANOTHER design for a still larger infant school-room is given in Figs. 192 and 193. The size being 40 feet long by 20 feet wide, enables accommodation to be given to 100 or 120 children. The construction is somewhat similar to the last, but the closets are taken as detached, or in a separate building. The framing is all 4 inches thick, the outer boarding and floor same as before, with a slated roof. The cost, erected complete, would be about £220. Any building of this description can be completed with a considerable amount of ornament if desired, while, being all lined inside, they form very comfortable warm rooms, either in summer or winter; in the latter season, again, there are now a very numerous variety of stoves, burning but little fuel, and very applicable for heating thoroughly such structures, thus when done with, the whole can readily be removed to some other site and easily re-erected, no brick or stonework being required. In districts where there is a sparse population, and where more durable materials and labour are both equally dear, these rooms will be found to give all the accommodation necessary, and to turn out quite satisfactory in all respects.

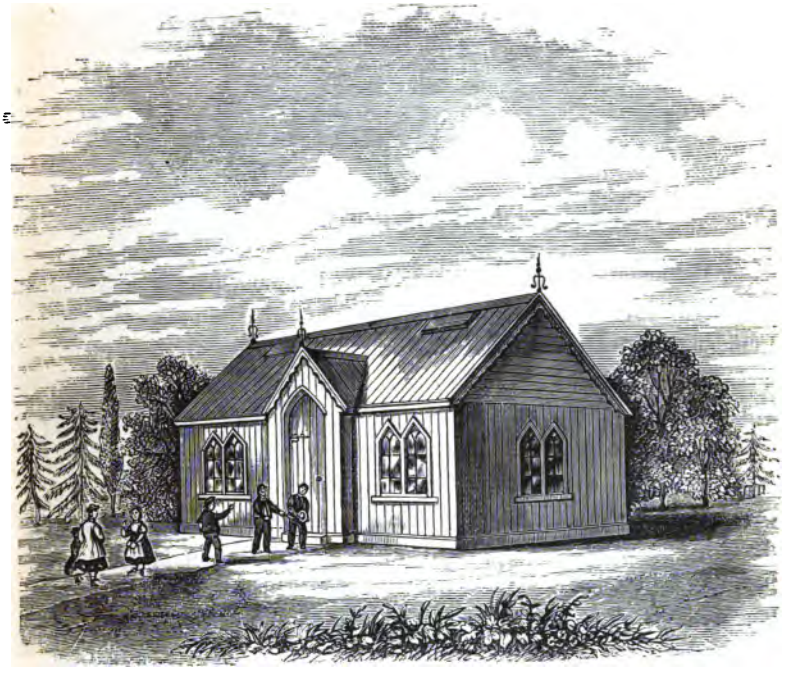


Fig. 192.

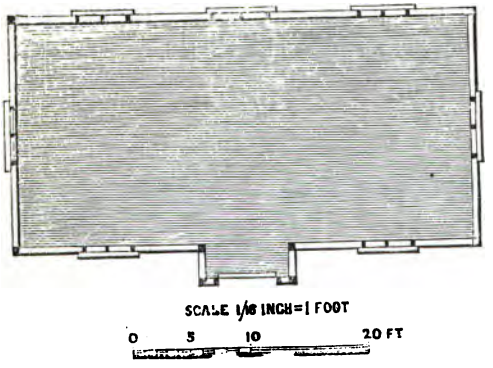


Fig. 193.

SCHOOL-ROOM.

FIGS. 194 and 195 show the elevation and ground plan of a school-room to be used as an adjunct to a church, chapel, or other ecclesiastical building. It is designed as being 50 feet long and 26 feet wide, and 12 feet high at the eaves, accommodating about 150 scholars There is a very effective porch and bell-turret, and like the other examples, it is capable of being treated with a considerable amount of ornamentation. The sides and ends are formed of 4 inch framing, covered with $\frac{3}{4}$ inch weather boarding, and the roof is slated, or, if desired, the roof can be covered with corrugated iron or zinc, but boarding is the most suitable material for the sides and ends. The great object to be borne in mind in these school buildings is that a proper amount of space is allowed for the number of persons accommodated, and that ample means of ventilation is secured. In this instance the latter is given by having a considerable space between the outside roof and inner ceiling, and numerous openings to the exterior allow of the air circulating freely. The cost of the building shown, fixed complete, would be about £346.

Fig. 194.

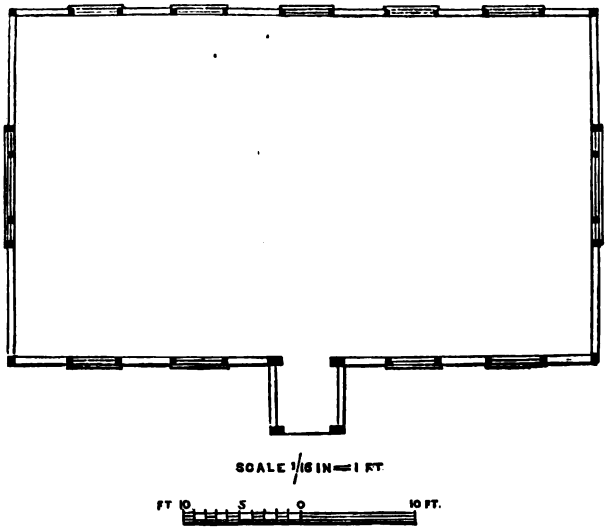


Fig. 195.

CHURCH TO SEAT TWO HUNDRED.

FIG. 196 is the elevation of a temporary church of which a ground plan is given in Fig. 197. The inside length is 45 feet and the breadth 25 feet, and this will seat 200 persons comfortably. The arrangement of seats, desk, pulpit, &c., would be somewhat as shown. There is also a bell-turret and porch provided, and the whole building is capable of considerable ornamental treatment. The framing throughout is 4 inches thick, and the roof has open framed principals, treated in accordance with the other portion of the building. It is well lighted, the sides being 12 feet high to the eaves. The outside roof covering may be of corrugated zinc, iron, or slates, and the sides may also be of zinc or iron fastened on the wood framing, but we prefer their being boarded. The whole of the interior, including the ceiling, is lined with thin matched boarding, and the various examples that have been constructed somewhat upon this pattern have given great satisfaction. The cost of this church, erected complete, would be about £385, not including the seats and inside fittings, which are best estimated for separately.

Fig. 196.

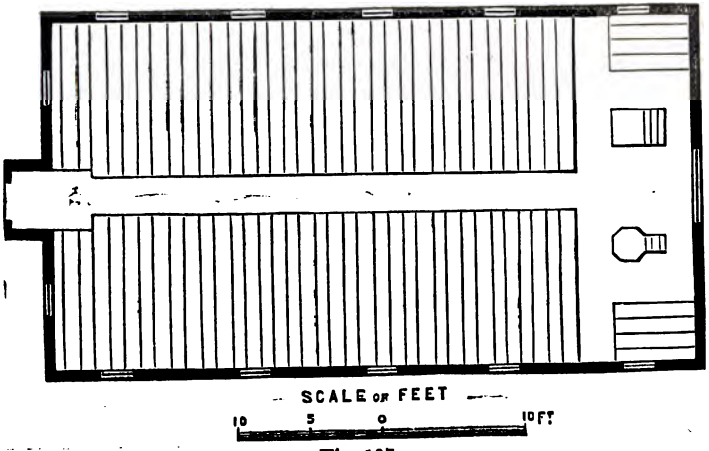
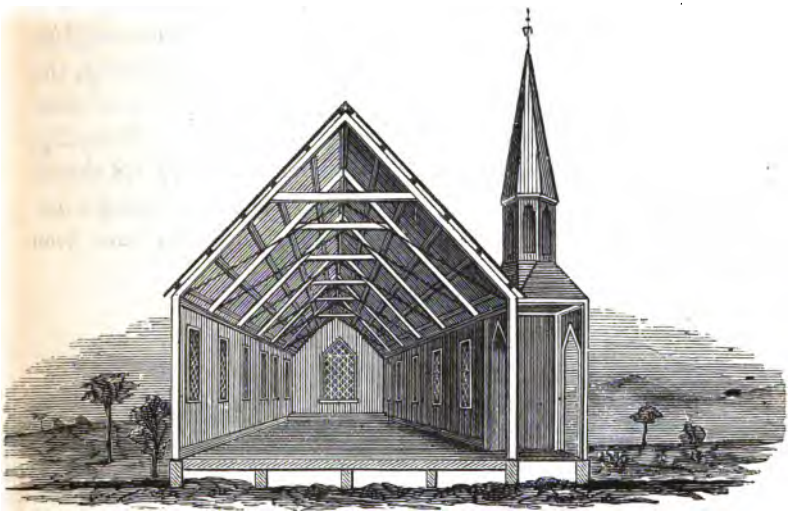


Fig. 197.

FIG. 198 shows a church, the dimensions of which being 70 feet in length and 30 feet in breadth, will accommodate 400 persons seated. The inside elevation is given in Fig. 199, with all the pews, &c., removed. This building is well-ventilated and lighted, has a porch and bell turret, and the construction is treated generally somewhat as the smaller one of the same kind formerly described. The cost of this, fitted complete with all interior fittings, would be about £715. Zinc of the Italian pattern laid on 3″ × 2″ rolls, makes a good outside covering for structures of this kind, and though somewhat expensive at first, the metal when done with can be sold for nearly its original cost, since it deteriorates very little by exposure to the weather. Square tiles are made in this material, also embossed to represent coursed rusticated masonry, and when painted, the effect of such treatment is very good.

Fig. 198.



SCALE FOR SECTION

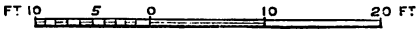


Fig. 199.

THE church shown in Fig. 200, and of which Fig. 201 is a ground plan, consists of a central nave 85′ 0″ long, × 22′ 0″ wide, and two side aisles each 85′ 0″ × 10′ 0″, and this building will accommodate 600 persons. It has in addition a porch, bell turret, and vestry-room, and forms a very complete structure. There can be a large quantity of ornamentation used in carrying out the design, and it may be covered totally with corrugated iron or zinc, but we ourselves prefer wood sides and slated roof. With floor throughout 1 inch thick on proper joists, and with seats, pulpit, and reading desk, the cost of this structure would be from £900 to £950 fixed complete. These buildings are of course intended for temporary use only, and are often, when they have served the purpose in the district in which they were originally built, removed and erected elsewhere. Generally, they readily find purchasers, and in the event of a very old church being restored or rebuilt, they are very serviceable in affording a congregation a temporary place of worship till such repairs have been executed.

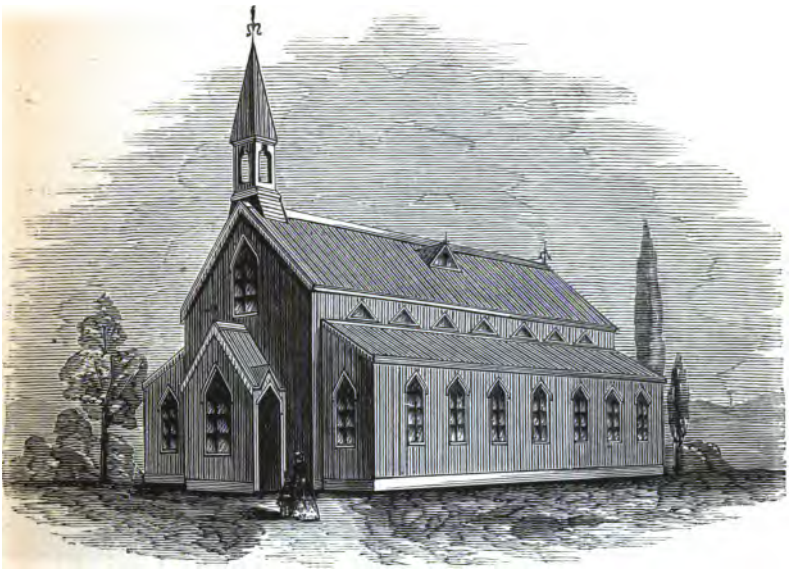
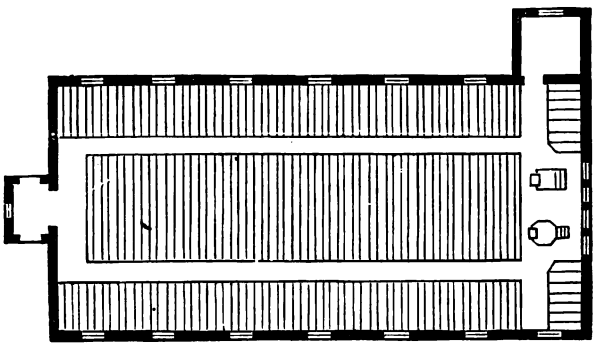


Fig. 200.



GROUND PLAN.

SCALE OF FT

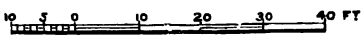


Fig. 201.

FIG. 202 shows the interior of a drill-hall or gymnasium built upon the principle so well-introduced by the late Captain Fowke, and elsewhere described (page 36). The light is admitted chiefly from the central skylight, and, the gable ends and louvring being placed at the eaves, it is well-ventilated. There are many purposes for which this building is adapted, such as Temporary Exhibitions, Flower Shows, &c. Its cost varies according to the size of the building, but an average price of £16 or £17 per 100ft. super. of ground covered would be a fair price for such a building erected complete, covered with felt. When a still larger space is required, as would, for instance, be necessary in the drill-hall of a large town, Fig. 203 would be more appropriate (see page 36), especially as any covering could be used, the construction of the principals allowing of any strength being attained. The cost of this covered with a durable material would vary from £20 to £22 per square covered according to the width or span of the building.

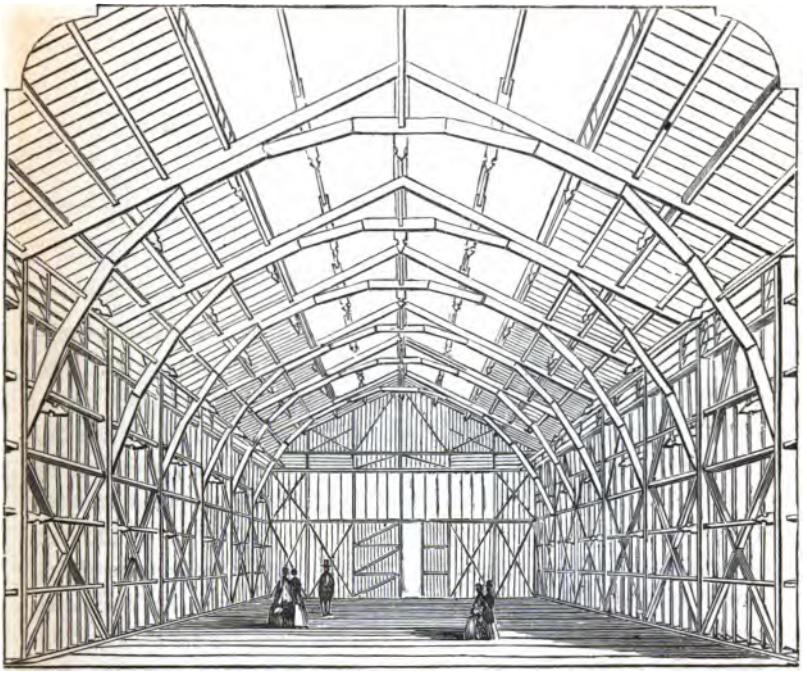


Fig. 202.

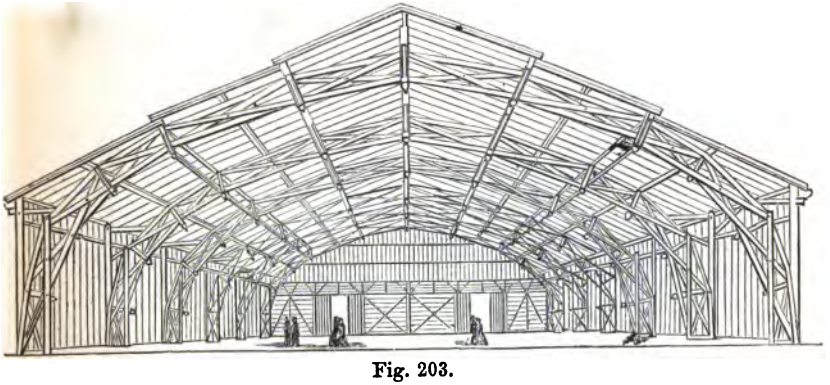


Fig. 203.

FIGS. 204 and 205 are roofs largely used in building sheds, warehouses, &c. The former has been already described at page 34. The advantage of this circular form of roof is that it can be made up to 100 feet span without inner or centre supports, and where a wide, clear space is required, it takes the lead of any other description of roof. Skylights and ventilators can be added where required readily. Its average cost would be from 30s. to 75s. per square of 100 feet super. for the roof only, fixed and measured over the outside of the curve, the great difference being accounted for by the increased expense as the span becomes greater. The roof shown in Fig. 205 forms also a most economical shed, and has this advantage, that being framed in the simplest manner and the contour being flat, by placing the principals from 5 feet to 6 feet apart, slates instead of felt can be used.

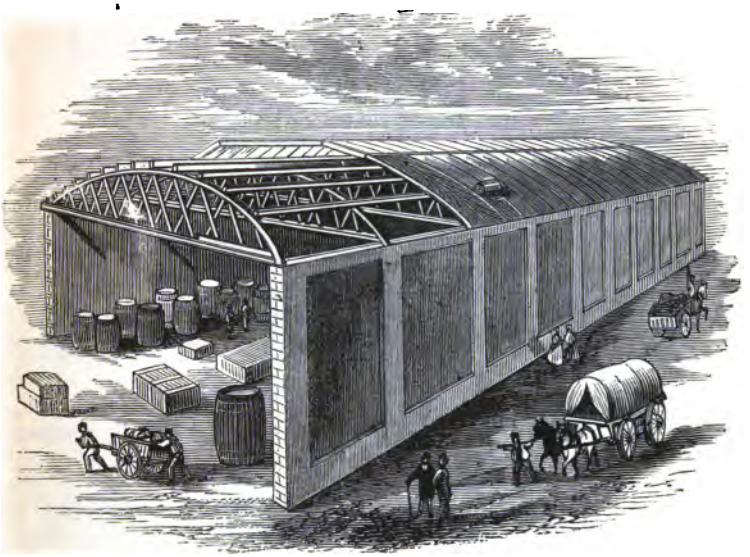


Fig. 204.

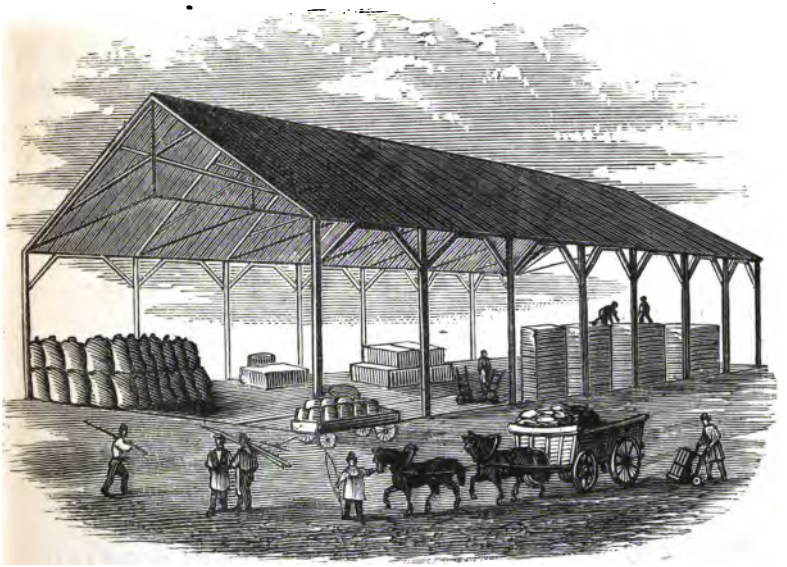


Fig. 205.

CHAPTER VIII.

STRAINS OF ROOFS, ETC.

Mode of arriving at the proper Dimensions of Scantlings when the total weight of the the load is ascertained; Tables of same for those most used in practice.

THE weights of roofing for the calculation of strains may be approximately taken in lbs. per ft. super. of ground covered as follows :—

	Angle of Roof with Horizon being.			
	15°	25°	35°	45°
Roof covering being tiles	34 lbs.	44 lbs.	54 lbs.	64 lbs.
,, felt—zinc, or sheet iron	21 ,,	30 ,,	38 ,,	47 ,,
,, pantiles or slates..	28 ,,	37 ,,	47 ,,	56 ,,

The variation per foot super. is due to the increased force of an horizontal wind, as the angle of roof becomes steeper and the greater weight of the materials in covering of same compared with one at a less angle to the horizon.

The sizes of scantling requisite for a king post roof similar in design to Fig. 206 may be derived from a list of initial numbers representing

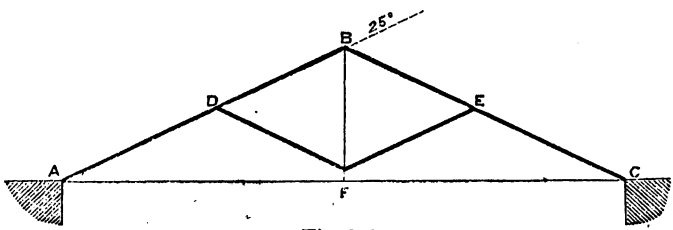


Fig. 206.

the intensity of the strain in terms of the whole weight carried by the roof, in each portion of the frame, at three different degrees of inclina-

tion, and this will apply to all the other tables of initial numbers here given for roofs.

Angle of Roof.	A B or + B C	D F or + E F	B F —	A C —
15°	·97	·25	·13	·93
25°	·71	·19	·13	·65
35°	·44	·12	·13	·36

F E is supposed to be parallel to A B.

The sign + means compression, — tension. When both signs are given it may be either a tensile or compressive strain.

In a wood roof with a straight tie beam as at A C, it is usual to treat that portion of the frame, as a beam bearing a weight distributed, equal to the tension thrown upon the king B F, or queen posts, where there are two of them. The intensity of the strain being known, the various Tables A, B, C, D, E, F, and G, given at the end of the work, are used thus—

Example: *Given a king post roof. Span* 20 *feet, covered with slates, angle being* 25°, *and the principals being placed* 10 *feet apart, to find the correct scantlings, small rafters* 18 *inches apart centre to centre, and having one purlin in centre of main rafter.*

Total weight on a bay of the roof = 20 × 10 × 37 = 7,400

Strain on tie beam A C = 7,400 × ·13 = 962 lbs. 20 feet long 7 × 3

,, strut D F = 7,400 × ·19 = 1,406 lbs. 5 feet long 3 × 1½

,, rafters A B = 7,400 × ·71 = 5,254 lbs. 11 feet long 5 × 3

,, king post B F = 7,400 × ·13 = 962 lbs.

,, small rafter $= \frac{20 \times 1{\cdot}5 \times 37}{4} =$ 278 lbs.

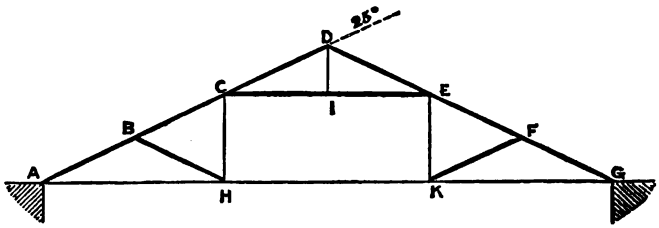
,, purlins $= \frac{7{,}400}{4} =$ 1,840 lbs. distributed.

,, ridge $= \frac{7{,}400}{8} =$ 925 lbs. do.

Now taking the tie beam A C on reference to table D, and assuming the framing to be 3 inches thick throughout, we take $\frac{962}{3}$ lbs. = 321 lbs., and being 20 feet long, with that weight distributed, we find the depth to carry 161 lbs. at the centre to be 7 × 3. The strut

D F being 5 feet long, and having a thrust on it equal to 1,406 lbs., we find by Table A should be at least $4\frac{1}{2}$ square inches, $3 \times 1\frac{1}{2}$ inches will, therefore, be ample. By the same Table A B is found to be 15 square inches, or say 5×3. The king post B F has a tensile strain of 962 lbs., and this by Table G could be made, at least $\frac{3}{4}$ inches square, at its centre with safety, but it is usually put in six or eight times that section. The small rafter carries 278 lbs. distributed over its length, which is 5 feet 6 inches long, and by Table D will do $3 \times 1\frac{1}{2}$ inches; by the same table, the size of the purlins and ridge will be found to be respectively 6×3 inches, and $6 \times 1\frac{1}{2}$ inches.

The strains on the queen post roof, shown in outline in Fig. 207, are as follows:—



Where A C = C E = E G × B H and K F are parallel to the rafters A D, D G.

Angle of Roof.	A D or + D G	C E +	B H + or K F	Along H K +	A G −	C H − or E K
15°	·97	·32	·16	·32	·93	·04
25°	·71	·22	·13	·22	·65	·07
35°	·44	·12	·09	·12	·36	·09

There is no strain on I D beyond half the weight of the tie C E.

Example: *In a timber roof covered with slates* 32 *feet span, angle* 25°, *distance between principals* 10 *feet, what are the correct sizes of scantlings?*

There the total weight = $32 \times 10 \times 37 = 11{,}840$ lbs.

The tension on each queen post = $11{,}840 \times \cdot 07 = 829$ lbs., or by table each would do $\frac{3}{4}$ in. square at the centre. This thrust is given on each side of the centre of the tie beam A G, and are together equal to a strain of about 1,275 lbs. in its centre, with this distributed

load, and assuming the tie beam to be 3 in. thick, the size should be, by Table D, about 10 × 3 in.

On strut B H or K F = 11,840 × ·13 = 1,539 lbs., 4 feet long, by Table A, say 3 × 1½.

On main rafters A D or D G = 11,840 × ·71 = 8,406 lbs., 18 feet long, say 5 × 3.

On collar C E .. .. } = 11,840 × ·22 = 2,605 lbs., 10 feet long,
Or straining piece H K } say 3 × 2½.

In this description of roof the centre space from H to K is sometimes used as a living-room or workshop, in that case, for the additional strains multiply the additional weight by the numbers given in the following Table, and add this to the strains given by the roof and its covering.

Angle of Roof.	A D or D G	C E or H K	B H or K F	A G	C H or E K
15°	1·60	·52	·26	1·54	·37
25°	1·17	·46	·19	1·07	·37
35°	·73	·40	·12	·60	·37

In Fig. 208 a queen post roof is shown in outline, in which the king rods and ties are of wrought iron, and the latter are slightly inclined to the horizon.

A B = B C = C D.

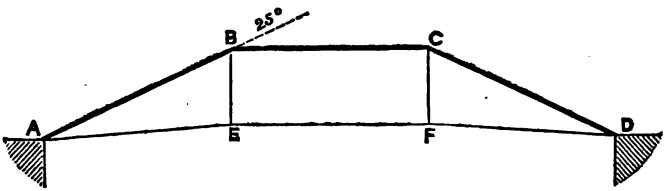


Fig. 208.

Angle of Roof.	A B + or C D	B C + or E F −	A E − or F D	B E − or C F	Inclination of Tie Rod to Horizon.
15°	1·63	1·61	1·62	·15	1 in 15
25°	1·16	1·12	1·13	·12	1 in 13
35°	·69	·63	·64	·08	1 in 10

Example: *In a timber roof with king and tie rods of iron,* 35 *feet span angle* 25°, *the principals being* 10 *feet apart, what should be the sizes of the scantlings, &c.?*

Total weight = 35 × 10 × 37 = 12,950 lbs.

On inclined tie rod A E or F D = 12,950 × 1·13 = 14,633 lbs., by Table G, 1¼ round.

On king rod B E or C F = 12,950 × ·12 = 1,554 lbs., by Table G, ½ in. round.

On main rafters A B or C D = 12,950 × 1·16 = 15,022 lbs., 13 feet long, by Table A, say 8 × 4.

On transom B C = 12,950 × 1·12 = 14,504 lbs., 13 feet long, by Table A, say 7 × 4.

Or tie rod E F, by Table G, 1¼ round.

In Fig. 209 another form of queen post roof is given, in which the centre portion is braced, this may be done either by the diagonals E H or C K, or by the struts dotted in at D H and D K.

N.B.—The tie beam is assumed to be divided into three equal portions, and the struts are therefore parallel to the rafters.

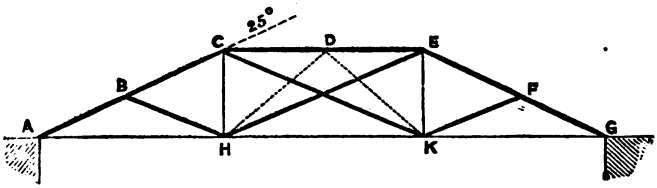


Fig. 209.

The strains are as given in the following Table :—

Angle of Roof.	A C or + E G	C E + or A G −	B H or + F K	H D or + K D	E H + or K C	C H − or E K	When H D or C K is used, then C H or E K becomes
15	·96	1·33	·16	·34	·33	·17	·25
25°	·71	·95	·12	·28	·25	·17	·25
35°	·45	·56	·08	·21	·16	·17	·25

Assuming that the principal is composed wholly of timber, the span and other particulars and the weight the same as the last example, then the dimensions of scantling would be as follows :—

On main rafter A C or E G = 12,950 × ·71 = 9,194 lbs., 11 feet long, or by Table A, say 7 × 3.

On transom E C = 12,950 × ·95 = 12,302 lbs., 13 feet long, or by Table A, say 9 × 3.

On strut B H or F K = 12,950 × ·12 = 1,554 lbs., 6 feet long, or by Table A, say 3 × 1½.

On diagonal C K or H E = 12,950 × ·25 = 3,237 lbs., 14 feet long by Table A, say 4 × 3.

On strut H D or D K = 12,950 × ·28 = 3,626 lbs., 9 feet long, say 3 × 3.

The strain on centre of the tie beam from the two queen posts will be found to be about 2,737 lbs. on each, and the queen posts C H or E K themselves = 12,950 × ·17 = 2,201 lbs., or by Table G 1⅛ square, and taking the tie beam, as 32 feet long, and having a distributed weight of 2,737 lbs., its scantling by Table D, will be about 6 × 4.

Fig. 210 is the outline of a roof generally composed of two wood or iron rafters, with wrought-iron or wood ties stretching from the foot of each rafter to a point higher than the centre of the other. The strains are as follows when the distance B C or C D equal two-fifths of the full length of rafter :—

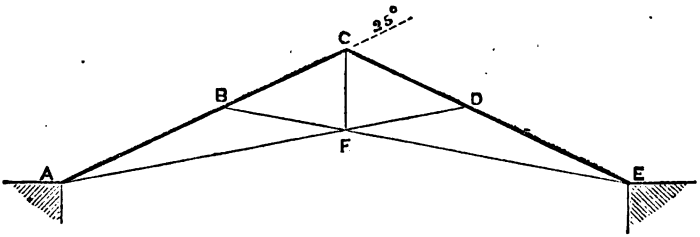


Fig. 210.

Angle of Roof.	A C + or C E	A D − or B E	C F −
15°	1·68	1·64	·37
25°	1·22	1·14	·37
35°	·76	·64	·37

Example: *In a roof of 25 feet span, principals 10 feet apart, angle 15° covering slate, what are the correct sizes of the scantlings, king and tie rods being iron?*

Total dead weight = 25 × 10 × 28 = 7,000 lbs.

On rafters A C and C E = 7,000 × 1·68 = 11,760 lbs., 14 feet long, by Table A, say 7 × 4.

On tie rods A D or B E = 7,000 × 1·64 = 11,480 lbs., by Table G, say, 1⅛ round.

On king rod C F = 7,000 × ·37 = 2,890 lbs. by Table G, say ⅝ round.

Fig. 211 is a roof on somewhat the same principle, but with the tie rod at an inclination to the horizon, the struts B F and D F are parallel to the rafters A C or C E.

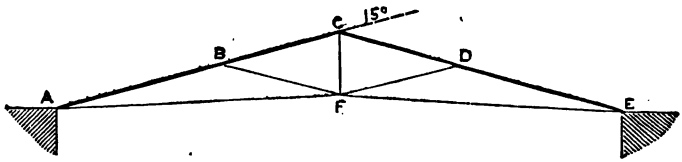


Fig. 211.

Angle of Roof.	A C + or C E	B F + or D F	A F − E F	C F −	Inclination of Tie to Horizon.
15°	1·27	·30	1·23	·30	1 in 15
25°	·90	·22	·84	·28	1 in 13
35°	·53	·13	·44	·25	1 in 10

A roof of this kind, constructed under the same conditions as the last, should, therefore, have scantlings as follows, viz. :—

On rafters A C or C E = 7,000 × 1·27 = 8,890 lbs., 14 feet long, by Table A, say 5½ by 4.

On strut B F or D F = 7,000 × ·30 = 2,100 lbs., 6 feet long, by Table A, if wood, say 3 × 2; if cast iron, by Table B, 1¼ inch diameter.

On tie rod A F or E F = 7,000 × 1·23 = 8,610 lbs., by Table G, ⅞ inch round.

On king rod C F = 7,000 × ·30 = 2,100 lbs., by Table G, ½ inch round.

In Fig. 212 the outline of a roof is shown in which, in addition to an iron tie rod inclined to the horizon there are also braces, the distance A B′ and E D′ being one-seventh, and B C and C D being two-sevenths, the full length of the rafter. Under these conditions the strains are as follows :—

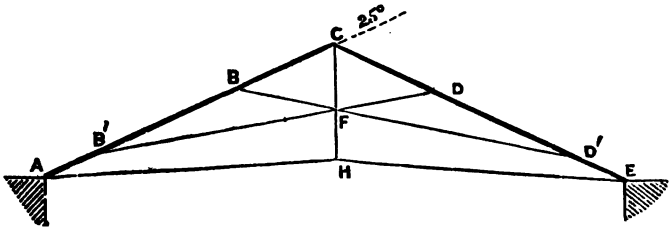


Fig. 212.

Angle of Roof.	A C + or C E	B F + or D F	A H − or E H	B' F + D' F	C H −	Inclination of Tie to Horizon.
15°	1·26	·44	·82	·40	·28	1 in 15
25°	·89	·31	·58	·25	·24	1 in 13
35°	·51	·18	·33	·10	·20	1 in 10

A B' } = 1-7th
E D' } rafter.
B C } = 2-7th
C D } rafter.

Example.—*In a roof* 40 *feet span, principals* 10 *feet apart, angle* 25°, *the whole being of timber with the exception of the tie rod and king bolt, required the scantlings, the covering being felt.*

Total weight = 40 × 10 × 30 = 12,000 lbs.

Main rafter A C or C E = 12,000 × ·89 = 10,680 lbs., 23 feet long, by Table A, 9 × 4.

Strut B F or D F = 12,000 × ·31 = 3,720 lbs., 7 feet long, by Table A, say 3½ × 3.

Tie rod A H or E H = 12,000 × ·58 = 6,960 lbs., by Table G, ⅞ inch round.

Tie B' F or D' F = 12,000 × ·25 = 3,000 lbs., 15 feet long, by Table A, say 4 × 3.

King rod C H = 12,000 × ·24 = 2,880 lbs., by Table G, say ⅝ inch round.

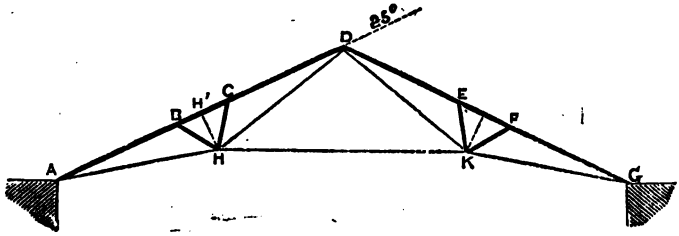


Fig 213.

M

The roof shown in outline in Fig. 213 is best constructed with the main rafters A D, D G, and the struts B H or H'H of wood or cast iron, and all the other portions of the truss in wrought iron, the depth of the truss at H'H varies as the angle of roof; we give, however, in the table of strains the proportions we have taken. The strains areas follows :—

Angle of Roof.	A D + or D G	K E + or B H	A H − or K G	H K −	H D − K D	When Strut is Square to Rafter H H' +	Ratio of H H' to Length of Rafter.
15°	1·58	·08	1·50	·80	·70	·12	One-twelfth.
25°	1·18	·07	1·11	·62	·53	·11	One-ninth.
35°	·78	·06	·67	·37	·35	·10	One-sixth.

Example.—*In a roof of this kind* 40 *feet span, principals* 10 *feet apart, covered with slates, what should be the size of the scantlings, angle of roof being* 35°?

Total weight = 40 × 10 × 47 = 18,800 lbs.

On rafter A D or D G = 18,800 × ·78 = 14,664 lbs., 24 feet long, by Table A, say 9 × 5.

On strut K E or B H = 18,800 × ·06 = 1,128 lbs., 5 feet long, by Table A, say 3 × 1½ inch; if cast iron, by Table B, say 1½ inch diameter.

On tie rod A H or K G = 18,800 × ·67 = 12,596 lbs., by Table G, 1⅛ inch diameter.

On tie rod at H K = 18,800 × ·37 = 6,956 lbs., by Table G, ⅞ inch diameter.

On tie rod H D or K D = 18,800 × ·35 = 6,580 lbs., by Table G, ⅞ inch diameter.

If the strut is at H H' = 18,800 × ·10 = 1,830 lbs., 4 feet long, by Table A, say 3 × 2; if of cast iron, by Table B, say 2 inches square.

In Fig. 214 a very similar roof is shown, but in this case the rafter is further subdivided, and the depths of the struts at centre of rafter as at D E being the same as before, the strains are as follows :—

The other side of the roof is strained, of course, in precisely the same manner.

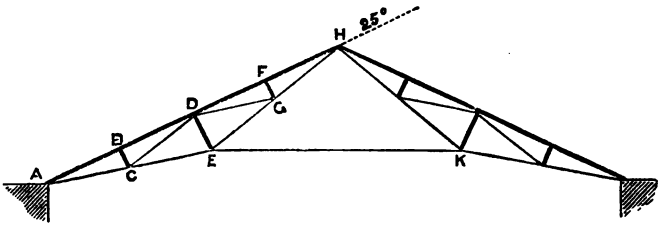


Fig. 214.

Angle of Roof.	A H +	D E +	F G + or B C	A E −	E H −	C D − or D G	E K −
15°	1·42	·12	·06	1·38	·69	·17	·70
25°	1·08	·11	·06	1·00	·54	·13	·50
35°	·74	·10	·05	·63	·38	·08	·30

A roof, therefore, erected under the same conditions as the last example, say at an angle of 15°, would require the following scantlings :—

Total weight = 40 × 10 × 28 = 11,200 lbs.

On main rafter A H = 11,200 × 1·42 = 15,904 lbs., 21 feet long, say 10 × 4. Table A.

On strut D E = 11,200 × ·12 = 1,344 lbs., 2 feet long, cast iron 1 in. diam. Table B.

On struts F G or B C = 11,123 × ·06 = 672 lbs., 1 foot long, cast iron ¾ in. diam. Table B.

On the tie A E =11,200×1·38=15,456 lbs. Table G. 1¼ in. diam.
On the tie E H =11,200× ·69= 7,728 lbs. do. ⅞ in. diam.
On the ties C D or D G=11,200× ·17= 1,904 lbs. do. ½ in. diam.
On the tie E K =11,200× ·70= 7,840 lbs. do. 1 in. diam.

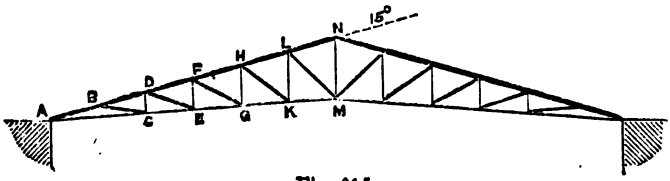


Fig. 215.

Fig. 215 gives the outline of the N roof so often used in railway stations, workshops, &c. The strains upon this kind of frame varies

as the number of divisions made in the rafter, and the inclination of that rafter and the tie to the horizon. We give below the initial numbers in principals divided from 12 to 6 on roofs at an angle of 15° and 25°.

Angle of Roof.	Main Rafter A N	Tie A M	1st Strut B C	2nd Strut D E	3rd Strut F G	4th Strut H K	5th Strut L M	1st Rod D C	2nd Rod F E	3rd Rod H G	4th Rod L K	5th Rod N M
With 12 divisions, as in woodcut.												
15°	1·29	1·26	·10	·11	·12	·13	·14	·02	·04	·06	·08	·21
25°	·75	·68	·05	·07	·08	·09	·11	·02	·04	·06	·08	·21
With 10 divisions.												
15°	1·29	1·26	·12	·13	·14	·16		·03	·05	·07	·20	
25°	·75	·68	·07	·08	·09	·11		·03	·05	·07	·20	
With 8 divisions.												
15°	1·29	1·26	·15	·16	·18			·03	·06	·18		
25°	·75	·68	·09	·11	·12			·03	·06	·18		
With 6 divisions.												
15°	1·29	1·26	·20	·22				·04	·16			
25°	·75	·68	·12	·15				·04	·16			
If the tie A M is made straight, and not inclined, then the strains are—												
For 12 divisions.												
15°	·96	·93	·08	·09	·10	·11	·13	·02	·04	·06	·08	·21
25°	·58	·54	·04	·06	·08	·09	·12	·02	·04	·06	·08	·21
With 10 divisions.												
15°	·96	·93	·10	·11	·13	·15		·03	·05	·07	·20	
25°	·58	·54	·06	·07	·09	·11		·03	·05	·07	·20	
With 8 divisions.												
15°	·96	·93	·12	·13	·15			·03	·06	·18		
25°	·58	·54	·09	·10	·12			·03	·06	·18		
With 6 divisions.												
15°	·96	·93	·16	·18				·04	·16			
20°	·58	·54	·10	·12				·04	·16			

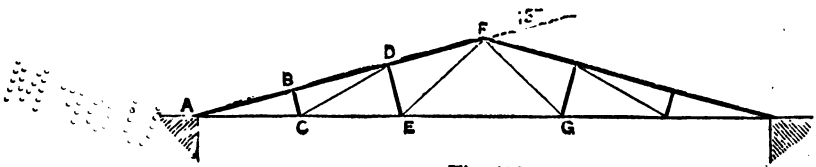


Fig. 216.

The roof shown in Fig. 216 is one somewhat similar to the last, but the braces B C and D E being perpendicular to the rafter act as struts and not as ties. The tie rod is straight also. This framing only looks well when divided into 6 or 4 equal parts, or when the angle of roof does not exceed 25°. The strains are as follows, divided into 6 as in woodcut:—

Angle of Roof.	Main Rafter A F	Main Tie A G	1st Strut B C	2nd Strut D E	1st Tie C D	2nd Tie F E
15°	·96	·93	·09	·12	·17	·16
25°	·60	·55	·08	·12	·09	·12
With 4 divisions.						
15°	·96	·93	·12		·23	
25°	·60	·55	·12		·14	

Figs. 217 and 218 are each of the kind known as the saw-toothed roof, and are largely used in weaving and other sheds, the light being thrown in from the inner edge of the tooth as at H C or H L. We have shown the strains, both with a straight tie and an inclined tie, as, if wrought iron is used, the latter design would be preferred; with a straight tie the strains become

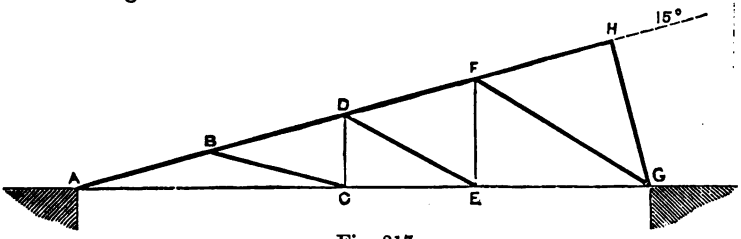


Fig. 217.

Angle of Long Rafter.	A H	A G	H G	1st Strut B C	2nd Strut D E	3rd Strut F G	1st Rod D C	2nd Rod F E
With 5 divisions, as in woodcut.								
15°	1·77	1·72	·52	·21	·24	·46	·06	·12
25°	·98	·88	·56	·12	·15	·48	·05	·10
With 4 divisions.								
15°	1·77	1·72	·52	·29	·50		·08	
25°	·98	·88	·56	·17	·47		·07	
With 3 divisions.								
15°	1·77	1·72	·52	·61				
25°	·98	·88	·56	·51				

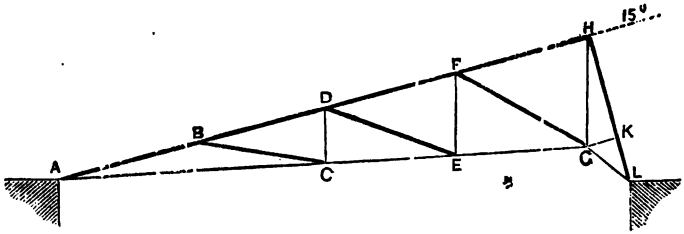


Fig. 218.

With an inclined tie as in Fig. 218, the strains become

Angle of long rafter.	A H	H L	A G	G L	1st Strut B C	2nd Strut D E	3rd Strut F G	G K	1st Tie D C	2nd Tie F E	3rd Tie H G
With 5 divisions, as in woodcut.											
15°	2·28	·52	2·20	·18	·27	·30	·32	·11	·06	·12	·30
25°	1·16	·55	1·05	·25	·13	·17	·20	·18	·06	·11	·24
With 4 divisions.											
15°	2·28	·52	2·20	·18	·37	·39		·11	·08	·28	
25°	1·16	·55	1·05	·25	·19	·22		·18	·08	·22	
With 3 divisions.											
15°	2·28	·52	2·20	·18	·55			·11	·24		
25°	1·16	·55	1·05	·25	·28			·18	·19		

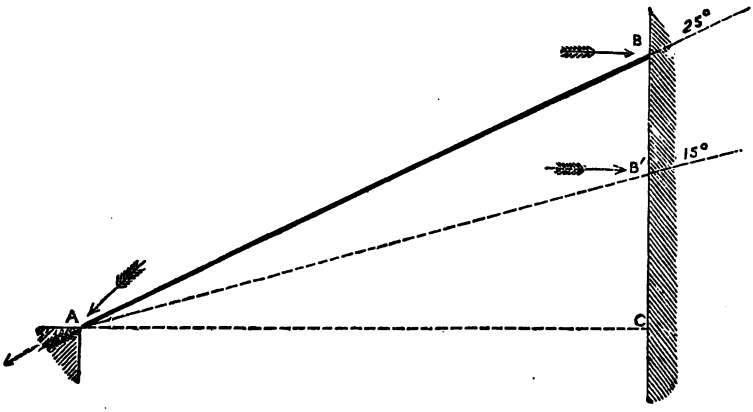


Fig. 219.

In a lean-to roof, such as is shown in outline by Fig. 219, there is a horizontal thrust at B, and also a pressure at A, acting at an angle greater than the inclination of the rafter A B; this latter thrust can be also treated as a transverse pressure acting in the centre of the rafter A B. With a distributed load at the various angles, the following initial numbers will represent the strain when the distributed weight = 1—

Inclination of Feam to Horizon.	Horizontal Pressure at B.	Pressure at A, and Angle of same.		Length of Rafter when Span = 1.	Transverse Pressure on Beam A B.
10°	1·41	1·50	19°	1·01	·25
15°	·92	1·05	28°	1·03	·24
20°	·68	·84	36°	1·06	·23
25°	·54	·73	43°	1·10	·22
30°	·43	·66	49°	1·15	·21
35°	·36	·61	54°	1·22	·20
40°	·29	·58	59°	1·30	·19
45°	·25	·55	63°	1·41	·18
50°	·21	·53	67°	1·57	·16
55°	·17	·52	70°	1·75	·14
60°	·14	·51	74°	2·01	·13

Example.—*In a lean-to roof covered with zinc, the rafters being* 5·0 *apart, the angle* 15°, *and the span* 20 *feet, what should be the dimension of the rafter?*

The weight here = 20 × 5 × 21 = 2,100 lbs.

2,100 × 1·05 = 2,205 lbs., 21·0 long, by Table A, say 6″ × 2″.

Length of rafter = 20·0 × 1·03 = 20·6 feet.

The transverse pressure will be 2,100 × ·24 = 504 lbs., by Table D, say 9″ × 2″.

The largest of these sections should be adopted.

In all cases where lean-to roofs are used, the strains will be precisely the same as those given in the foregoing tables, for one half the roof only.

In the same way we give below the series of numbers applicable to trussed beams, girders, &c., but for want of space we have only selected a few of those most in use. Fig. 220 shows the simplest kind of trussed beam, when loaded all over the strains are,

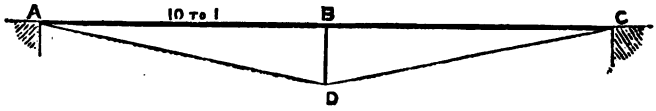


Fig. 220.

Ratio of Span to Depth.	A C +	A D — or C D	B D +
Loaded all Over.			
10 to 1	1·28	1·25	·50
15 to 1	1·90	1·88	·50
Loaded in Centre or Rolling Load.			
10 to 1	2·56	2·50	1·00
15 to 1	3·80	3·76	1·00

It will be found by a process precisely similar to that adopted in the examples given of roofs, that a trussed wood beam, whose depth to span is 1 to 10, to carry 2 tons loaded all over the span being 30 feet, would require at A C a section of 30 inches, say 6 inches × 5 inches, the tie rod A D should be $\frac{3}{4}$ inch diameter, and the cast-iron strut would do $1\frac{1}{2}$ diameter. If it was not trussed it would require by Table D a beam about 12 inches × 7 inches to carry the weight.

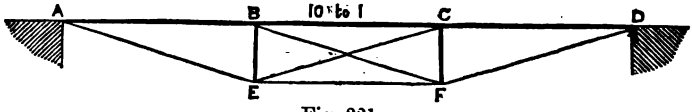


Fig. 221.

In Fig. 221 there are two struts with diagonal braces, in which case the strains are,

Ratio of Depth to Span.	A D + or E F	A E — or D F	C E — or B F	B E + or C F
When Loaded in Centre.				
1 in 10	2·50	2·34	1·17	·67
1 in 15	3·76	3·32	1·66	·67
When Loaded all Over.				
1 in 10	1·25	1·31	·66	·50
1 in 15	1·88	1·92	·96	·50
With a Rolling Load.				
1 in 10	2·50	2·62	1·31	1·00
1 in 15	3·76	3·83	1·92	1·00

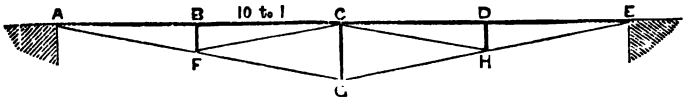


Fig. 222.

With the trussed beam shown in Fig. 222 the strains are,

Ratio of Depth to Span.	A E +	A G — or E G	C H — or C F	B F + or D H	C G +
		When Loaded in Centre.			
1 in 10	2·50	2·56	1·28	·50	1·00
1 in 15	3·76	3·80	1·88	·50	1·00
		When Loaded all Over.			
1 in 10	1·25	1·28	·96	·38	·50
1 in 15	1·88	1·90	1·43	·38	·50
		With a Rolling Load.			
1 in 10	2·50	2·56	1·92	·75	1·00
1 in 15	3·76	3·80	2·86	·75	1·00

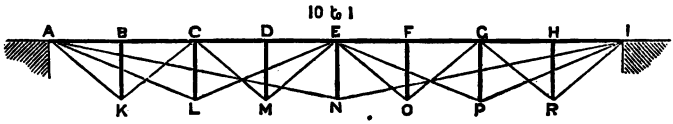


Fig. 223.

With the beam trussed as in Fig. 223, being a simple combination to trusses similar to that shown in Fig. 220, the following are the strains when the top member is divided into eight portions, as in woodcut, and also when divided into four only. We treat the remaining trusses as having a rolling load only when loaded, all over half the strain will be given.

With a Rolling Load.

Ratio of Length to Depth. D	A I	I N or A N	A L or I P	E L or E P	C K, A K, I R and G R	C M or G O	E O or E M	B K, D M, E N, F O or H R	G P C L
				8 Divisions, as in Diagram.					
8 to 1	2·00	2·07	1·12	1·69	·71	1·04	1·23	1·00	·75
10 to 1	2·50	2·56	1·34	2·00	·82	1·14	1·30	1·00	·75

With a Diagram lettered in the same rotation as Fig. 223.

Ratio of Length to Depth.	A E	A G or E G	A F or E H	C F or C H	B F, D H, or C G
4 Divisions.					
8 to 1	2·00	2·07	1·12	1·69	1·00
10 to 1	2·50	2·56	1·34	2·00	1·00

N.B.—When the beam is loaded all over, take half these strains.

In the American trussed beam shown in Fig. 224, we give the strains as below for beams having the top number divided into 4, 6, and 8, equal lengths as the case may be, the lettering in all cases following the rotation given in the diagram. These strains are taken as a rolling load; when loaded all over, take half these strains.

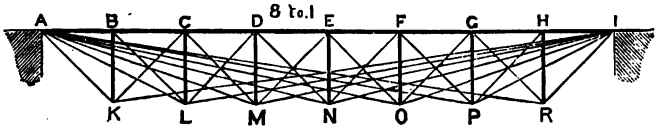


Fig. 224.

Loaded with a Rolling Load.

Ratio of Length to Depth.	A I	I N A N	A K I R	BL, KC HP, GR	D L, C M G O, F P	E M, D N F N, E O	I K A R	I L A P	I M A O	H R B K	A L I P	A M I O	C L G P	D M F O	E N
8 Divisions, as in Diagram.															
8 to 1	2·00	2·07	·71	·53	·37	·17	·89	1·52	1·92	1·00	1·12	1·57	·75	·50	·25
10 to 1	2·50	2·56	·80	·62	·40	·21	1·10	1·91	2·37	1·00	1·35	1·94	·75	·50	·25

Ratio of Length to Depth.	A G	A K G K	A H G M	B I, C H, E M, F L	A I G L	A M G H	B H F M	A L G I	E L C I	D K	C K, D I, D L, E K
6 Divisions.											
8 to 1	2·00	2·07	·85	·54	1·45	1·15	1·00	1·83	·67	·34	·25
10 to 1	2·50	2·56	·97	·66	1·75	1·43	1·00	2·25	·67	·34	·31

Ratio of Length to Depth.	A E	A G E G	E H A F	E F A H	C F, B G, C H, D G	B F D H	C G
4 Divisions.							
8 to 1	2·00	2·07	1·12	1·53	·57	1·00	·50
10 to 1	2·50	2·56	1·35	1·88	·67	1·00	·50

In the parallel lattice girder shown in Fig. 225, the strains vary as the angle of end strut, and as the ratio of length to depth of girder. As this is a most useful type of girder, we give the strains for a rolling load in cases, where the diagonals vary from 6° to 45°. There is no strain on the upright rod, where it is in the exact centre of the girder. As before, for a beam loaded all over take half the strains given.

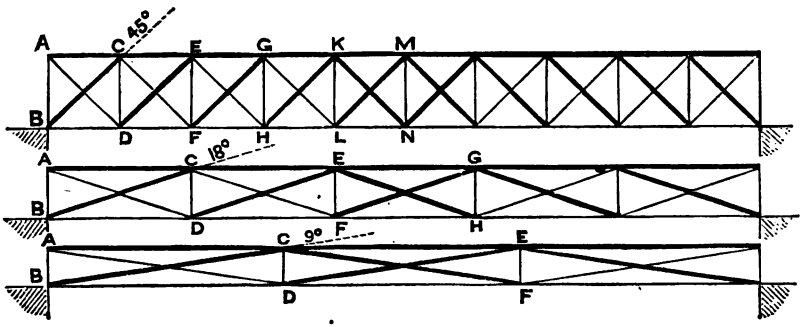


Fig. 225.

Angle of 1st Diag.	Ratio of Length to Depth.	Top or Bottom Member AM or BN.	1st Rod.	2nd Rod.	3rd Rod.	4th Rod.	5th Rod.	1st Diag.	2nd Diag.	3rd Diag.	4th Diag.	5th Diag.
					10 Divisions.							
45°	10 to 1	2·50	1·00	·80	·60	·40	·20	·71	·57	·43	·29	·15
34°	15 to 1	3·76	1·00	·80	·60	·40	·20	·91	·72	·54	·36	·18
					9 Divisions.							
42°	10 to 1	2·50	1·00	·78	·56	·34	·11	·75	·59	·42	·26	·09
31°	15 to 1	3·76	1·00	·78	·56	·34	·11	·97	·75	·54	·33	·11
					8 Divisions.							
30½°	10 to 1	2·50	1·00	·75	·50	·25		·80	·60	·40	·20	
28°	15 to 1	3·76	1·00	·75	·50	·25		1·03	·78	·52	·26	
22°	20 to 1	5·00	1·00	·75	·50	·25		1·35	1·01	·67	·34	
					7 Divisions.							
37°	10 to 1	2·50	1·00	·72	·43	·14		·84	·60	·37	·14	
25°	15 to 1	3·76	1·00	·72	·43	·14		1·13	·82	·50	·18	
19°	20 to 1	5·00	1·00	·72	·43	·14		1·50	1·07	·65	·23	
					6 Divisions.							
31°	10 to 1	2·50	1·00	·67	·33			·97	·65	.32		
21½°	15 to 1	3·76	1·00	·67	·33			1·31	·87	·44		
16½°	20 to 1	5·00	1·00	·67	·33			1·67	1·12	·64		

Angle of 1st Diag.	Ratio of Length to Depth.	Top or Bottom Member AM or BN	1st Rod.	2nd Rod.	3rd Rod.	4th Rod.	5th Rod.	1st Diag.	2nd Diag.	3rd Diag.	4th Diag.	5th Diag.
					5 Divisions.							
27°	10 to 1	2·50	1·00	·60	·20			1·13	·68	·22		
18°	15 to 1	3·76	1·00	·60	·20			1·34	·82	·31		
14°	20 to 1	5·00	1·00	·60	·20			2·08	1·26	·42		
					4 Divisions.							
22°	10 to 1	2·50	1·00	·50				1·33	·68			
14½°	15 to 1	3·76	1·00	·50				1·91	·96			
11½°	20 to 1	5·00	1·00	·50				2·53	1·27			
					3 Divisions.							
16½°	10 to 1	2·50	1·00	·33				1·72	·58			
11°	15 to 1	3·76	1·00	·33				2·47	·82			
8½°	20 to 1	5·00	1·00	·33				3·28	1·09			
					2 Divisions.							
11½°	10 to 1	2·50	1·00					2·56				
7½°	15 to 1	3·76	1·00					3·84				
6°	20 to 1	5·00	1·00					5·12				

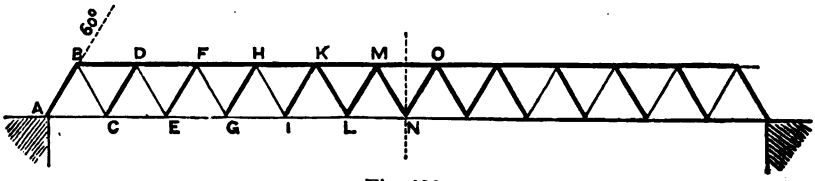


Fig. 226.

The trussed beam or warren girder shown in Fig. 226 is supposed in the following Table of strains to be composed of equilateral triangles, so that the end strut is always the same inclination to the horizon, and A B = B C = A C. The strains vary as the weight and depth of the girder. They are taken also as for a rolling load, and if the weight is distributed divide the result by 2 :—

Loaded all over.—The Diagram represents a Beam with 12 Divisions.

Ratio of Length to Depth nearly.	No. of Divisions.	Top or Bottom Member B M or A M	Number of Strut from Pier. 1st	2nd	3rd	4th	5th	6th	No. of Strut inclined to opposite Pier. 1st	2nd	3rd	4th	5th	6th
14 to 1	12	3·50	·58	·48	·38	·28	·18	·07	·54	·45	·35	·26	·17	·07
13 to 1	11	3·15	·58	·49	·39	·29	·20	·10	·52	·41	·32	·21	·11	
12½ to 1	10	2·87	·58	·46	·34	·22	·10		·52	·41	·29	·18	·06	
10½ to 1	9	2·69	·58	·47	·36	·24	·13		·52	·39	·27	·14		
9 to 1	8	2·30	·58	·43	·28	·13			·50	·36	·21	·07		
8 to 1	7	2·00	·58	·45	·31	·18			·50	·34	·17			
7 to 1	6	1·76	·58	·38	·18				·47	·29	·10			
5¾ to 1	5	1·44	·58	·35	·12				·47	·24				
4¾ to 1	4	1·16	·58	·29					·42	·15				

As an example of the use of these Tables in girders, we will endeavour to find the strains and proper scantlings of an American trussed beam similar to that shown in Fig. 224, supposing the span to be 50 feet, loaded all over equally with a weight equal to 15 tons, the weight of girder being 40 cwt. (nearly the actual weight), and its depth $\frac{1}{8}$th of the span, or 6 feet 3 inches long. The top beam and struts are supposed to be of timber, and the truss rods wrought iron.

Total weight = 33,600 + 4,480 = 38,080 lbs.

						Table A, say	
				Lbs.	Long.	Ins.	Ins.
Strain on Top Member A I =	38,080	×	1·00	= 38,080	50·0	13	× 11
,, 1st Strut, H R or B K =	,,	×	·50	= 19,040	6·3	$5\frac{1}{2}$	× $5\frac{1}{2}$
,, 2nd ,, C L or G P =	,,	×	·375	= 14,280	6·3	$4\frac{3}{4}$	× $4\frac{3}{4}$
,, 3rd ,, D M or F O =	,,	×	·25	= 9,520	6·3	4	× 4
,, Centre ,, E N =	,,	×	·125	= 4,760	6·3	3	× 3
					By Table G.		
,, 1st truss rod, A K or I R =	,,	×	·355	= 13,518	$1\frac{1}{4}$ ins. round.		
,, ,, A L or I P =	,,	×	·56	= 21,324	$1\frac{1}{2}$	,,	
,, ,, A M or I O =	,,	×	·785	= 29,892	$1\frac{3}{4}$	,,	
,, ,, A N or I N =	,,	×	1·035	= 39,412	2	,,	
,, ,, A O or I M =	,,	×	·96	= 36,556	2	,,	
,, ,, A P or I L =	,,	×	·76	= 28,940	$1\frac{3}{4}$	,,	
,, ,, A R or I K =	,,	×	·445	= 16,945	$1\frac{2}{5}$	,,	
,, 1st pair, diagonals, B L =	,,	×	·265	= 10,091	$1\frac{1}{5}$	,,	
,, 2nd ,, C M =	,,	×	·185	= 7,004	$\frac{7}{8}$	,,	
,, 3rd ,, D N =	,,	×	·085	= 3,236	$\frac{5}{8}$	,,	

And now a few words as to the computation of strains in connection with cranes. Take the simplest form of pillar crane as shown in Fig. 227 If the distance from A to B is made by scale, equal to the weight D it is supposed to lift, then the line B C drawn parallel to the tie, and measured by the same scale, will give the tensile strain on the tie B C, and the line A C drawn parallel to the strut, and measured by the same scale, the compressive strain on A C. The strain on the pillar is best represented by drawing a horizontal line, *a* C from C, the highest position of the load till it joins the extended line A B at *a*. It may then be represented, as a lever similar to that shown in Fig. 228, in which the fulcrum *f* represents the surface of the ground; the distance *f* P′ = A *a*, and the weight of masonry W round the base of the

column A B should be proportioned, according to its distance from *f*, as compared with the length *f* P′ in this case : the masonry must be

Fig. 227.

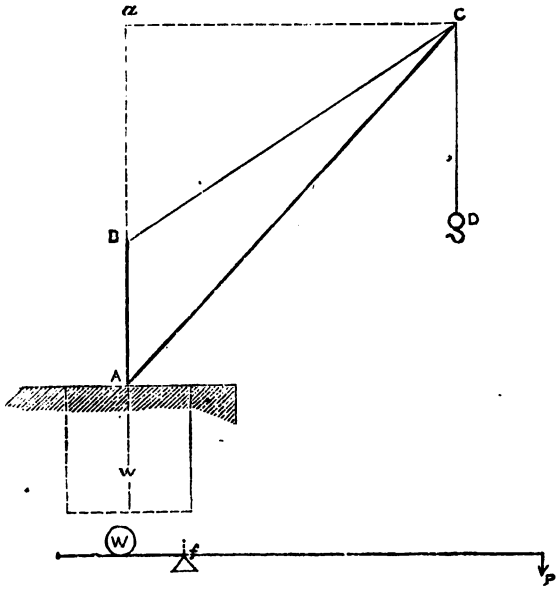


Fig. 228.

considerably heavier than the actual weight it is required to lift; indeed, such a crane is kept upright only by the weight of masonry, or other work placed round the base of the pillar, and this weight should be at least double that theoretically required to keep the lever balanced.

In the derrick crane shown in Fig. 229 in the same way, if B C represents by scale the weight E, B D and C D will by the same scale show the tensile strain on the derrick chain B D and the compression on C D respectively. With the jib lowered to C the strain will under the same conditions be represented by the line B *d*, C *d*, or if it is raised to *d*, then B *d* C *d* will represent the respective strains. In all cases the strain on the jib (where the weight to be raised is the same) will be alike, and the tie only will vary. The thrust at C is generally taken by a piece of timber laid from C to the foot of the

guy at A, and its magnitude will be represented by a horizontal line measured from the same scale and drawn from the weighted end of the jib, say D *c* or *d* to the upright B C. This strain, however, is not always a compressive one, as it is evident that when the weight is swung round so as to be near the foot of the guy at A″, that the sill A C is in tension, hence it should be large enough and of such

Fig. 230.

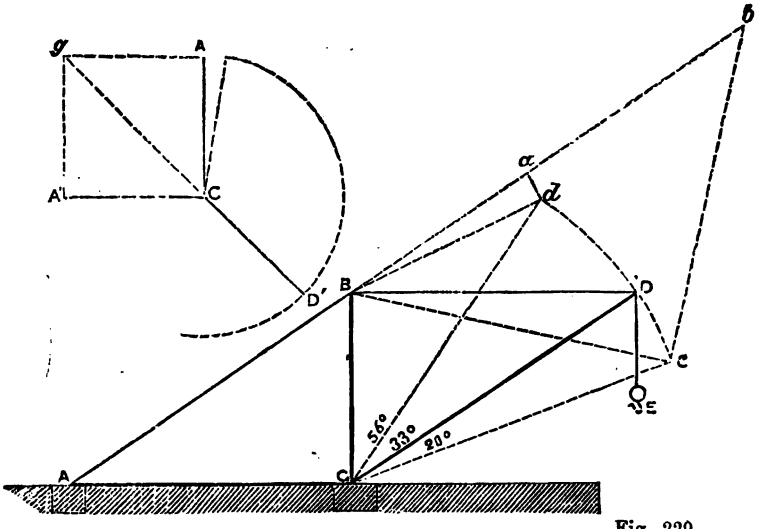


Fig. 229.

material as will resist either a tensile or compressive strain. The strain is greatest when the crane is in the same plane as the guy, and with the jib at its least inclination to the horizon as at C. The tensile strain on the guy A B when the load is at *d*, is best found by a line drawn at right angles to the chain B *d*, till it meets with the extended line A B at the point *a*, or at *b* should the weight be lowered to C. B *a* or B *b* will then represent by scale the strains on the guy. It is evident by a glance at the diagram Fig. 230 that these strains become the greatest that require to be provided for in the structure. The ends of the guy at A″ should have as much masonry built round them as will equal the weight to be carried.

In the sheer legs or poles shown in Fig. 231, B C represents the position of the sheer legs, and A B that of the guy, and with a load

W hanging over from the perpendicular if B *b* be made by scale to equal that load, *b a* be drawn parallel to the poles, A B being extended till the lines meet in the point *a*, then B *a* will equal the tension on

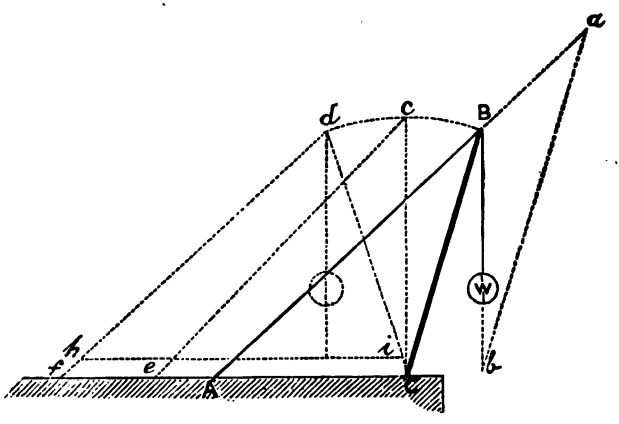


Fig. 231.

A B, and *a b* the compression on B C. Should the sheer legs be upright, C *i* and C *e* will in the same manner represent the respective strains, and should the weight be slung inward to *d*, *d h* and *d i* will be both in compression to the magnitude given by a scale of which *c i* represents the whole weight carried. The guy A B should, it will be observed, be strong enough to resist either of the utmost compressive or tensile strains, but the poles B C are always in compression.

Fig. 232 is a skeleton diagram of a steam crane working upon a centre pivot at *h*, with the jib at one side partly counterbalanced by the weight of the steam boiler, &c., and having rollers at *i* travelling upon a circular rail laid on the ground. The crane is kept in position, when loaded, by nuts acting as a collar on the centre pin *h*. If A B be made to represent by scale the weight D, then A C and B C by the same scale gives the strain on the guy and jib respectively. The pressure on the guide rail *i* and the upward pull upon the centre pin at *h* is found by treating it as bent lever, loaded at the end of one arm by the weight D; thus let the line *h i* be drawn from the surface of the guide rail to the under side of the nut at *h*, draw the line *f d*

through the point h at right angles to $h\,i$, then taking the weight D and multiplying it by the horizontal distance b from the guide rail or fulcrum to the weight D, and dividing it by the distance a from the guide rail to the centre pin, make $d\,f$ by scale equal to the product

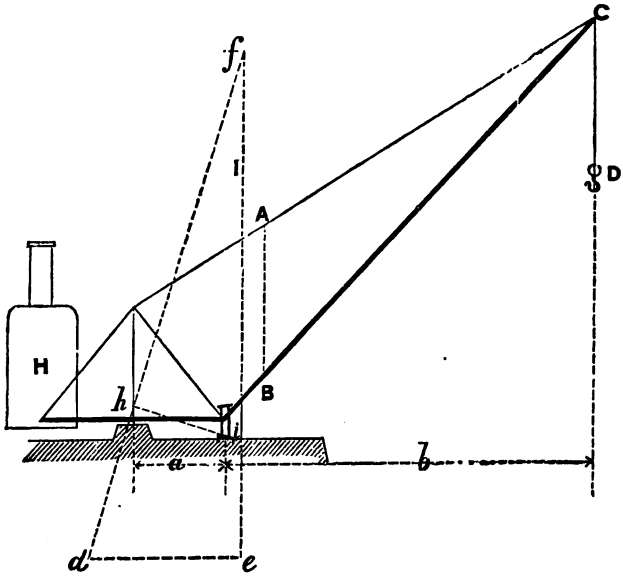


Fig. 232.

resolve this into its horizontal and vertical components $d\,e$ and $e\,f$. Then $e\,f$ equals the upward pull upon the centre pin, and $d\,e$ the horizontal thrust on the same. The pressure upon the guide rail is equal to $\frac{D\,(a + b)}{a}$, or the weight multiplied by its distance from the centre pivot, and divided by the distance of the other end of the lever to the guide rail.

CHAPTER IX.

THE following Tables are given so as readily to enable the reader to arrive at the scantlings of materials to resist the various strains constantly occurring in practice. In all cases the weights given are those which can safely be used, and vary under certain conditions already allowed for from $\frac{1}{8}$ to $\frac{1}{10}$, the breaking weight. A short explanation will be best given by a few examples :—

Table A (Compression).

I. A piece of oak or fir 10 feet long, and 6 inches diameter, will carry safely 16,497 lbs. A piece of the same material 20 feet long to carry the same weight would require to have a diameter of $7\frac{1}{2}$ inches, or be about 7 inches square on side if square.

Table B (Compression).

II. A solid cast-iron column 8 feet long, and 2 inches diameter will carry safely $1\frac{1}{2}$ tons, and weigh $9{\cdot}818 \times 8 = 78\frac{1}{2}$ lbs.

III. A hollow cast-iron column 3 inches outside diameter, and 2 inches inside diameter 8 feet long will carry $5\frac{1}{5}$ tons, and weigh 98lbs., here safe weight $= 6{\cdot}7 - 1{\cdot}5 = 5\frac{1}{5}$ tons, and weight $= (22{\cdot}089 - 9{\cdot}818) \times 8 = 98{\cdot}1$ lbs.

If the diameters given in the Table represent the greatest diagonal of a square hollow column, multiply the weight shown by ·63 for the safe weight, thus :—

IV. A cast-iron column $2\frac{7}{8}$ inches on side, and $\frac{1}{2}$ inch thick, its length being 14 feet, will have for its greatest diagonal 4 inches, and will carry 2·9 tons.

$7{\cdot}3 - 2{\cdot}6 = 4{\cdot}7 \times {\cdot}63 = 2{\cdot}9$ tons.

If the diameters given in the Table represent the least width of a strut having as its section the form of a + multiply the weights shown by ·37.

V. A strut, with a cross section of 3 inches $\times$ 3 inches $\times$ $\frac{1}{2}$ inch 10 feet long would carry 1·3 tons.

$4{\cdot}6 - 1{\cdot}0 = 3{\cdot}6 \times 3{\cdot}7 = 1{\cdot}3$ tons.

N.B.—If the strut is hinged at one end take $\frac{1}{4}$th this result as a safe weight.

TABLE C (COMPRESSION).

VI. Example: What weight will a wrought-iron tube carry safely, whose external diameter is 2 inches, thickness $\frac{1}{8}$ inch, and length 10 feet?

Here $\frac{2}{120} = \frac{1}{60}$ ratio of diameter to length,

its area equals $3{\cdot}1416 - 2{\cdot}4052 = {\cdot}7364$ square inches.

Then $\cdot 7364 \times 1445 = 1064$ lbs. safe weight.

VII. If the column was 2 feet diameter $\frac{3}{8}$ inches thick, and 20 feet long

Then $\frac{2}{20} = \frac{1}{10}$ ratio of diameter to length.

Its area equals $452{\cdot}39 - 424{\cdot}55 = 27{\cdot}84$ square inches.

Then $27{\cdot}84 \times 3{,}700 = 103{,}008$ lbs. safe weight.

VIII. In a square tube, however, of the same sectional area, the side of the square being the same as the diameter of the last example, its thickness would be ·58 inches, and the side 24 inches; here

ratio of thickness to side $= \frac{\cdot 58}{24} = {\cdot}024$, and the multiplier being ·62, hence $103{,}008 \times {\cdot}62 = 63{,}864$ lbs. safe weight.

TABLE D (TRANVERSE STRAINS).

IX. A beam of elm or Riga fir 20 feet long, 10 inches deep, and 1 inch thick, will carry safely a load of 370 lbs. at its centre, or 740 lbs. distributed; if it is made 10 inches wide, the depth being the same, it will carry 3,700 lbs. at its centre, or 7,400, distributed.

X. With a 10 feet bearing what size of a deal 3 inches thick will carry 2,700 lbs. loaded at its centre?

Here $\frac{2,700}{3} = 900$ lbs., it should, therefore, be 11 inches deep.

For the safe load in centre of cast-iron beams multiply the weight in the Table by the area of bottom flange in square inches.

N.B.—The top flange of cast-iron beams is generally $\frac{1}{4}$th of the bottom flange.

XI. What weight will a cast-iron beam carry in its centre, the top flange being one-fourth the area of the bottom flange, which contains 3 square inches, its depth being 7 inches, and length 8 feet?

Here $453 \times 3 = 1,359$ lbs. at centre, or 2,718 lbs. distributed.

For the safe load in centre of a wrought-iron plate beam, the top flange being double the area of the bottom flange, multiply the weight given in the Table by the area of the bottom flange in square inches, and again by 2·5.

XII. In a wrought-iron plate beam 15 inches deep, 20 feet between supports, and having a sectional area in bottom flange of 5 square inches, what will be the safe load?

Here $832 \times 5 \times 2{\cdot}5 =$ 10,400 lbs. in centre,
or 20,800 lbs. distributed.

Table E (Transverse Strains).

We have given this Table as wrought-iron solid rolled joists and girders are now coming into extensive use for these as well as many other purposes, for which they are well adapted. We only regret not being able to add the compressive strength of these beams.

Tables F and G (Tensile).

These Tables give the relative tensile strength as well as lineal weight, &c., of chains, hemp, and wire ropes, and also of square and round iron and wood.

TABLE A.

Safe Load in lbs. for Oak and Fir Columns.

Length in Feet.	Diameter of Column in Inches and Equal Area in Square Inches.								
	1 ·785	2 3·141	3 7·068	4 12·566	5 19·63	6 28·27	7 38·48	8 50·26	9 63·61
1	2,195	2,385	5,476	9,800	15,355	22,153	30,172	39,435	49,940
2	1,646	2,195	5,264	9,576	15,131	21,918	29,948	39,211	49,705
3	1,153	1,926	4,939	9,228	14,772	21,548	29,568	38,830	49,324
4	817	1,646	4,547	8,780	14,291	21,056	29,064	38,315	48,809
5	593	1,377	4,121	8,265	13,720	20,451	28,436	37,676	48,160
6	448	1,153	3,696	7,705	13,081	19,756	27,708	36,915	47,376
7	336	974	3,304	7,145	12,398	18,995	26,891	36,064	46,941
8	268	817	2,934	6,529	11,692	18,177	26,006	35,123	45,516
9	212	694	2,609	6,048	10,987	17,348	25,076	34,115	44,452
10	179	593	2,318	5,544	10,281	16,497	24,102	33,058	43,321
11		515	2,072	5,073	9,609	15,646	23,116	31,964	42,145
12		448	1,848	4,648	8,971	14,817	22,220	30,844	40,913
14		336	1,489	3,897	7,795	13,227	20,171	28,571	38,393
16		268	1,209	3,292	6,764	11,760	18,300	26,342	35,851
18		212	1,008	2,788	5,891	10,460	16,564	24,203	32,580
20		179	840	2,385	5,140	9,296	14,974	22,187	30,923
22		145	716	2,050	4,513	8,288	13,529	20,305	28,627
24		123	616	1,792	3,976	7,403	12,252	18,952	26,746
26		112	526	1,568	3,516	6,641	11,099	17,024	24,472
28			459	1,377	3,136	5,969	10,080	15,612	22,624
30	For teak × 1·15		403	1,220	2,800	5,387	9,172	14,324	20,932
35	,, larch × ·72		302	929	2,161	4,222	7,324	11,648	17,304
40	,, elm × ·66		235	728	1,713	3,382	5,947	9,576	14,414
45			180	582	1,332	2,766	4,905	7,979	11,726
50			145	470	1,142	2,296	4,032	6,708	10,292

TABLE A.—(*Continued.*)

Safe Load in lbs. for Oak and Fir Columns.

Length in Feet.	Diameter of Column in Inches and Equal Area in Square Inches.								
	10 78·54	11 95·03	12 113·09	13 132·73	14 153·93	15 176·71	16 201·06	17 226·98	18 254·46
1	61,667	74,638	88,838	104,272	120,948	138,857	157,998	178,386	199,998
2	61,443	74,401	88,603	104,048	120,724	138,633	157,774	178,147	199,763
3	61,062	74,020	88,222	103,667	120,321	138,241	157,393	177,766	199,382
4	60,536	73,494	87,696	103,129	119,806	137,715	156,856	177,228	198,844
5	59,875	72,833	87,024	102,457	119,134	137,032	156,172	176,545	198,161
6	59,091	72,038	86,217	101,651	118,316	136,124	155,344	175,716	197,332
7	58,184	71,108	85,288	100,699	117,364	135,251	154,392	174,753	196,388
8	57,176	70,078	84,224	99,635	116,289	134,131	153,294	173,656	195,249
9	56,067	68,947	83,070	98,488	115,113	132,955	152,062	172,412	194,006
10	54,880	67,715	81,816	97,160	113,769	131,622	150,718	171,057	192,640
11	53,636	66,416	80,460	95,782	112,358	130,188	149,262	169,579	191,150
12	52,326	65,038	79,038	94,304	110,846	128,643	147,694	167,988	189,537
14	49,593	62,126	75,980	91,134	107,576	125,294	144,267	164,516	186,009
16	46,771	59,091	72,744	87,740	104,036	121,643	140,515	160,664	182,069
18	43,948	55,977	69,395	84,769	100,296	117,745	136,483	156,520	177,844
20	41,660	52,864	66,001	80,528	96,420	113,680	132,449	152,140	173,320
22	38,472	49,806	62,608	76,643	92,478	109,491	127,859	147,571	168,593
24	35,896	46,838	59,270	73,169	88,513	105,426	123,379	142,867	163,699
26	33,465	43,933	56,033	69,563	84,560	101,001	118,854	138,084	158,681
28	31,180	41,272	52,908	66,046	80,684	96,779	114,318	133,268	153,608
30	29,052	38,718	49,918	62,641	76,888	92,624	109,816	128,452	148,512
35	24,393	32,972	43,086	54,745	67,939	82,667	98,907	116,648	135,867
40	20,574	28,156	37,217	47,790	62,137	73,550	88,737	105,459	123,704
45	16,934	23,452	31,337	40,678	51,508	63,862	77,739	95,132	112,234
50	14,963	20,854	28,044	36,624	46,648	58,150	71,176	85,736	101,841

TABLE B.

Safe Load for Solid Cast-iron Columns in Tons.

Length in Feet.	Diameter of Column in Inches and Weight per Foot run in Lbs.								
	1 2·45	2 9·81	3 22·08	4 39·27	5 61·35	6 88·35	7 120·26	8 157·08	9 198·80
1	4·43	53·	231·	651·	1,454·	2,803·	4,883	7,898	12069
2	1·36	16·	71·1	200·	447·	863·	1.503	2,431	3714
3	·68	8·3	35·7	100·	224·	433·	755	1,220	1864
4	·41	5·1	21·9	61·	137·	265·	462	748	1143
5	·28	3·4	15·	42·	94·	181·	316	512	782
6	·21	2·5	11·	30·	69·	133·	232	375	573
7	·16	1·9	8·4	23·	53·2	102·	178	288	441
8	·12	1·5	6·7	19·	42·4	81·7	142	230	351
9	·10	1·2	5·5	15·	34·7	66·9	116	188	288
10	·08	1·0	4·6	13·	29·	55·9	97	157	240
11	·07	·91	3·9	11·	24·6	47·5	82	134	204
12	·06	·78	3·3	9·5	21·2	41·0	71	115	176
14	·05	·60	2·6	7·3	16·3	31·5	55	88	135
16	·04	·48	2·07	5·8	13·	25·1	43	70	108
18	·03	·39	1·69	4·7	10·6	20·5	35	58	88
20	·02	·33	1·42	4·0	8·9	17·2	29	48	74

TABLE B.—(*Continued.*)

Length in Feet.	Diameter of Column in Inches and Weight per Foot run in Lbs.								
	10 245·43	11 296·97	12 353·43	13 414·78	14 481·05	15 552·23	16 628·32	17 709·31	18 795·31
1	17,636	24,855	33,998	45,352	59,219	75,915	95,771	119,129	146,347
2	5,428	7,650	10,464	13,958	18,226	23,366	29,476	36,666	45,044
3	2,724	3,839	5,252	7,006	9,148	11,728	14,795	18,404	22,608
4	1,670	2,354	3,220	4,296	5,610	7,191	9,072	11,285	13,683
5	1,143	1,611	2,203	2,940	3,839	4,921	6,208	7,722	9,487
6	838	1,181	1,616	2,156	2,815	3,609	4,553	5,664	6,958
7	645	909	1,243	1,659	2,166	2,777	3,504	4,358	5,354
8	514	724	991	1,322	1,726	2,213	2,792	3,473	4,267
9	420	593	811	1,082	1,413	1,811	2,285	2,843	3,492
10	351	495	678	904	1,181	1,514	1,910	2,376	2,920
11	299	421	576	769	1,004	1,288	1,625	2,021	2,483
12	258	363	497	663	866	1,111	1,401	1,743	2141
14	198	279	382	510	666	854	1,078	1,341	1,648
16	158	223	305	407	531	681	859	1,069	1,310
18	129	182	249	333	435	557	703	875	1,075
20	108	152	208	278	363	466	588	731	898

TABLE C.

Safe weight in lbs. for wrought iron round and square tubes when used as columns.

Round Tubes.

Ratio of External Diameter to Length.	Lbs. per Square Inch of Section.
1/60 to 1/80	1.445
1/50 to 1/60	2,234
1/30 to 1/50	3,039
1/20 to 1/30	3 462
1/10 to 1/20	3,700

Square Tubes.

When the ratio of thickness of plate to the longest side of column as below

	·010,	multiply result by	·38
From	·010 to ·020,	do.	·54
,,	·020 to ·036,	do.	·62

TABLE D.

Safe weight in lbs. (when loaded in centre)* of elm or Riga fir beams, the uniform breadth being taken at one inch.

Length in Feet.	Depth in Inches.											
	1	2	3	4	5	6	7	8	9	10	11	12
1	74	296	666	1,184	1,850	2,664	3,626	4,736	5,994	7,400	8,954	10,656
2	37	148	333	592	925	1,332	1,813	2,368	2,997	3,700	4,477	5,328
3	24	98	222	394	616	888	1,208	1,578	1,998	2,466	2,984	3,552
4	18	74	166	296	462	666	906	1,184	1,498	1,850	2,238	2,664
5		59	133	236	370	532	725	947	1,198	1,480	1,790	2,131
6		49	111	197	308	444	604	788	999	1,233	1,492	1,776
7		42	95	169	264	380	518	676	856	1,057	1,279	1,522
8		37	83	148	231	333	453	592	749	925	1,119	1,332
9			74	131	205	296	402	526	666	822	994	1,184
10			66	118	185	266	362	473	599	740	895	1,065
12			55	98	154	222	302	399	499	616	746	888
14	For pitch pine × 1·4			84	132	190	259	388	428	528	639	761
16	,, ash or oak × 1·5			74	115	166	226	296	374	462	559	666
18	,, teak × 2·2				102	148	201	263	333	411	497	592
20					92	133	181	236	299	370	447	532
22	For the safe load in centre of cast					121	164	215	279	339	410	488
24	iron beams multiply the weight here					111	151	199	249	308	373	444
26	given by the area of bottom flange.						140	184	231	286	346	412
28							129	169	214	264	319	380
30	For the safe load in centre of							157	199	246	298	355
35	wrought iron plate beams, multiply								171	211	255	304
40	the weight here given by the area of									185	223	266
45	bottom flange, and again by 2·5.											236
50												
55												
60												

* If the load is distributed it will carry double the weight given in this table, and if the load is a moving one take 5-7ths of the tabular weight.

TABLE D—*Continued.*

Safe weight in lbs. (when loaded in centre)* of elm or Riga fir beams, the uniform breadth being taken at one inch.

Length in feet.	Depth in Inches.											
	13	14	15	16	17	18	19	20	21	22	23	24
1	12,506	14,504	16,650	18,944	21,386	23,976	26,714	29,600	32,634	35,816	39,146	42,624
2	6,253	7,252	8,325	9,472	10,693	11,988	13,357	14,800	16,317	17,908	19,573	21,312
3	4,168	4,834	5,550	6,314	7,128	7,992	8,904	9,866	10,878	11,938	13,048	14,208
4	3,126	3,626	4,162	4,736	5,396	5,994	6,678	7,400	8,158	8,954	9,786	10,656
5	2,501	2,900	3,330	3,788	4,277	4,795	5,342	5,920	6,526	7,363	7,829	8,524
6	2,084	2,417	2,775	3,157	3,564	3,996	4,452	4,933	5,439	5,969	6,524	7,104
7	1,786	2,072	2,378	2,706	3,055	3,425	3,816	4,228	4,662	5,116	5,592	6,089
8	1,563	1,813	2,081	2,368	2,698	2,997	3,339	3,700	4,079	4,477	4,893	5,328
9	1,389	1,611	1,850	2,104	2,376	2,664	2,968	3,288	3,626	3,979	4,349	4,736
10	1,250	1,450	1,665	1,894	2,138	2,397	2,671	2,960	3,263	3,681	3,914	4,262
12	1,042	1,208	1,387	1,578	1,782	1,998	2,226	2,466	2,719	2,984	3,262	3,552
14	893	1,036	1,189	1,353	1,527	1,712	1,908	2,114	2,331	2,558	2,796	3,049
16	781	906	1,040	1,184	1,349	1,498	1,669	1,850	2,039	2,238	2,446	2,664
18	694	805	925	1,052	1,188	1,332	1,484	1,644	1,813	1,989	2,174	2,368
20	625	725	832	947	1,069	1,198	1,335	1,480	1,631	1,840	1,957	2,131
22	573	664	762	868	980	1,098	1,224	1,356	1,495	1,662	1,798	1,953
24	521	604	693	789	891	999	1,113	1,233	1,359	1,492	1,631	1,776
26	508	558	643	732	827	927	1,033	1,145	1,262	1,380	1,514	1,650
28	496	518	594	676	763	856	954	1,057	1,165	1,279	1,398	1,524
30	416	483	555	631	712	799	890	986	1,087	1,227	1,304	1,420
35	357	414	475	541	611	685	763	845	932	1,051	1,118	1,217
40	312	362	416	473	534	599	667	740	815	920	978	1,065
45	277	322	370	420	475	532	593	657	725	795	869	947
50		290	333	378	427	479	534	592	652	736	782	852
55			305	346	391	439	489	542	597	674	717	781
60			277	315	356	399	445	493	543	613	652	710

* If the load is distributed it will carry double the weight given in this table, and if the load is a moving one take 5-7ths of the tabular weight.

TABLE E.

Sale Load (Distributed) for Solid Rolled Joists and Girders, and weight per foot run in lbs.

Usual Section.	Weight per foot run in lbs.	Length between Supports in feet. 6	8	10	12	14	16	18	20
Depth. Breadth.	lbs.								
4 × 1¾	7	4,480	3,360	2,800	2,240				
4¾ × 1¾	8	5,040	4,480	3,360	2,800				
6¼ × 2	11		7,280	6,720	5,600	5040	2,800		
7 × 2¼	14		11,760	9,520	8,960	6720	5,040	4480	
8 × 2½	15		14,560	11,760	10,080	8960	7,280	6720	5,040
6¼ × 3	16		13,680	11,200	8,960	7280	5,600		
8¾ × 2¾	17			14,000	11,760	10080	8,960	7840	7,280
6¼ × 3	18	20,160	13,680	11,648	10,080	8512	6,944	6272	
7 × 4	21	24,640	17,920	13,440	11,424	9408	7,840	6944	6,048
9¼ × 4	25		26,380	20,160	15,680	13440	11,200	10080	8,960
10 × 4¼	35			29,120	24,640	22400	17,920	15680	13,440
12 × 5	46			49,280	42,560	35840	29,120	26880	24,640

Various modifications of strength by rivetting these beams together, and in some cases adding plates at top or bottom, can be made thus:—

No. 1. With a plate on top only its strength is increased by.. .. 1·4

No. 2. ,, top and bottom ,, ,, ,, ... 1·9

No. 3. Taking two of the above beams, rivetting one above the other, thus doubling its depth.. .. .. .. ,, ,, ,, ... 3·6

No. 4. Adding to No. 3 a plate at top and bottom the ratio of the width to the depth of beam being as ·09 to 1 .. ,, ,, ,, ... 4·6

No. 5. Placing two of the beams side by side and rivetting a plate on the top and bottom the width of which equals the depth .. .. ,, ,, ,, ... 3·6

No. 6. Placing three of the beams side by side, adding a top and bottom flange, the width of which to the depth is as 1·4 to 1· .. .. .. ,, ,, ,, ... 5·4

No. 7. Taking two of the double beams No. 3, placing them side by side, adding a plate top and bottom .. .. .. ,, ,, ,, ... 8.4

TABLE F.

Weight per Foot Lineal and Safe Load in lbs. on Chains, and the Sizes of Hemp and Wire Round, and Flat Ropes to Carry Corresponding Weights.

Chains.			Hemp Ropes.		Round Wire Ropes.		Flat Wire Ropes.	
Size of Chain.	Weight per foot.	Safe Load.	Circumference of rope.	Weight per foot.	Circumference of rope.	Weight per foot.	Section of rope.	Weight per foot.
			Inches.		Inches.			
$\frac{5}{16}$	·91	1,428	$3\frac{1}{2}$	·46	$1\frac{1}{2}$	2·19		
$\frac{3}{8}$	1·33	2,058	$4\frac{1}{4}$	·79	$1\frac{3}{4}$	2·87		
$\frac{7}{16}$	2·5	2,800	5	·96				
$\frac{1}{2}$	2·33	3,668	$5\frac{3}{4}$	1·11	2	3·87		
$\frac{9}{16}$	3·	4,676	$6\frac{1}{2}$	1·63	$2\frac{1}{4}$	4·94	$2\frac{1}{8}\times\frac{1}{2}$	1·67
$\frac{5}{8}$	3·67	5,712	7	1·88			$2\frac{3}{4}\times\frac{1}{2}$	2·
$\frac{11}{16}$	4·5	6,972	8	2·5	$2\frac{1}{2}$	6·87	$2\frac{7}{8}\times\frac{9}{16}$	2·34
$\frac{3}{4}$	5·33	8,232	$8\frac{3}{4}$	3·11	$2\frac{3}{4}$	7·25	$3\frac{1}{4}\times\frac{5}{8}$	3·
$\frac{13}{16}$	6·16	9,716	$9\frac{1}{2}$	3·5	3	8·50	$3\frac{3}{4}\times\frac{3}{4}$	3·67
$\frac{7}{8}$	7·16	11,200	10	3·83	$3\frac{1}{4}$	9·87		
$\frac{15}{16}$	8·16	12,936	$10\frac{3}{4}$	4·67	$3\frac{3}{4}$	11·19	$4\frac{1}{4}\times\frac{13}{16}$	4·34
1	9·33	15,008	$11\frac{1}{2}$	5·08	$4\frac{1}{4}$	16·44	$5\times\frac{7}{8}$	5·
$1\frac{1}{16}$	10·5	16,689	$12\frac{1}{4}$	6·	$4\frac{1}{2}$	18·75		
$1\frac{1}{8}$	11·83	18,704	13	6·5	$4\frac{3}{4}$	21·44	$6\times\frac{7}{8}$	6·17
$1\frac{3}{16}$	13·16	20,776	$13\frac{3}{4}$	7·5	5	24·56		
$1\frac{1}{4}$	14·5	22,848	$14\frac{1}{2}$	8·08				
$1\frac{5}{16}$	16·	25,368	$15\frac{1}{4}$	9·33				
$1\frac{3}{8}$	17·6	27,888	16	10·				

TABLE G.

Safe Tensile Strain in lbs. on Wrought Iron, Round and Square; also on Square Sections of Red or Pitch Pine.

Wrought Iron.			Sq. Red or Pitch Pine.	Wrought Iron.			Red or Pitch Pine Square.
Round.		Square.		Round.		Square.	
Diam.	Safe Load.	Safe Load.	Sfe. Ld.	Diam.	Safe Load.	Safe Load.	Safe Load.
$\frac{3}{8}$	1,402	1,785	281	$1\frac{3}{4}$	30,600	39,015	6,109
$\frac{1}{2}$	2,422	3,187	500	$1\frac{7}{8}$	34,935	44,497	7,031
$\frac{5}{8}$	3,901	4,972	781	2	40,035	51,000	8,000
$\frac{3}{4}$	5,610	7,140	1,125	3	90,015	114,750	18,000
$\frac{7}{8}$	7,622	9,690	1,531	4	160,140	204,000	32,000
1	9,945	12,750	2,000	5	250,282	318,750	50,000
$1\frac{1}{8}$	12,546	15,937	2,531	6	360,442	459,000	72,000
$1\frac{1}{4}$	15,555	19,890	3,125	7	490,620	624,750	98,000
$1\frac{3}{8}$	18,487	23,842	3,781	8	640,815	816,000	128,000
$1\frac{1}{2}$	22,440	28,687	4,500	9	811,027	1,032,750	162,000
$1\frac{5}{8}$	26,137	33,405	5,281				

Maleable Bar Iron—Weight of a Lineal Foot.

Size	inches	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Square bars	lbs.	·208	·325	·468	·638	·833	1·05	1·30	1·57	1·87
Round ,, ...	,,	·163	·255	·368	·501	·654	·82	1·02	1·23	1·47
Size	inches	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{5}{16}$
Square bars	lbs.	2·20	2·55	2·92	3·33	3·76	4·21	4·70	5·20	5·74
Round ,, ...	,,	1·72	2.0	2·30	2·61	2·95	3·31	3·69	4·39	4·51
Size	inches	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{5}{8}$	$1\frac{11}{16}$	$1\frac{3}{4}$	$1\frac{13}{16}$	$1\frac{7}{8}$
Square bars	lbs.	6·30	6·88	7·50	8·15	8·80	9·50	10·20	10·69	11·71
Round ,, ...	,,	4·95	5·40	5·89	6·40	6·91	7·46	8·01	8·60	9·20
Size	inches	$1\frac{15}{16}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$
Square bars	lbs.	12·52	13·33	15·05	16·87	18·80	20·80	22·96	25·20	27·55
Round ,, ...	,,	9·83	10·47	11·82	13·25	14·76	16·36	18·03	19·79	21·63
Size	inches	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$	4
Square bars	lbs.	30·	32·55	35·20	37·96	40·80	43·80	46·87	50·05	53·33
Round ,, ...	,,	23·56	25·56	27·65	29·82	32·07	34·40	36·81	39·31	41·88
Size	inches	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{1}{2}$	$4\frac{5}{8}$	$4\frac{3}{4}$	$4\frac{7}{8}$	5	$5\frac{1}{8}$
Square bars	lbs.	56·71	60·20	63·80	67·50	71·30	75·20	79·21	83·33	93·2
Round ,, ...	,,	44·54	47·28	50·11	53·01	56·	59·06	62·21	65·45	73·2
Size	inches	$5\frac{1}{2}$	$5\frac{3}{4}$	6	$6\frac{1}{4}$	$6\frac{1}{2}$	$6\frac{3}{4}$	7	$7\frac{1}{4}$	$7\frac{1}{2}$
Square bars	lbs.	102·2	111·8	121·7	132·0	142·8	154·0	165·6	177·7	190·1
Round ,, ...	,,	80·3	87·8	95·6	103·7	112·2	121·0	130·0	139·5	149·3
Size	inches	8	$8\frac{1}{2}$	9	$9\frac{1}{2}$	10	$10\frac{1}{2}$	11	$11\frac{1}{2}$	12
Square bars	lbs.	216·3	244·2	273 8	305·1	337·9	372·7	409·0	447·0	486·7
Round ,, ...	,,	169·9	191·8	215·0	239·6	266·3	292·7	321·2	351·1	382·2

Flat Rolled Iron.—Weight of a Lineal Foot.

Width of Iron.	$\frac{1}{4}$ inch thick.	$\frac{5}{16}$ in. thick.	$\frac{3}{8}$ inch thick.	$\frac{7}{16}$ in. thick.	$\frac{1}{2}$ inch thick.	$\frac{9}{16}$ in. thick.	$\frac{5}{8}$ inch thick.	$\frac{11}{16}$ in. thick.	$\frac{3}{4}$ inch thick.	$\frac{13}{16}$ in. thick.	$\frac{7}{8}$ inch thick.	$\frac{15}{16}$ in. thick.	1 inch thick.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	·833	1·04	1·25	1·45	1·66	1·87	2·08	2·29	2·50	2·70	2·91	3·12	3·33
$1\frac{1}{8}$	·937	1.17	1·40	1·64	1·87	2·10	2·34	2·57	2·81	3·04	3·28	3·51	3·75
$1\frac{1}{4}$	1·04	1·30	1·56	1·82	2·08	2·34	2·60	2·86	3·12	3·38	3·64	3·90	4·16
$1\frac{3}{8}$	1·14	1·43	1·71	2·	2·29	2·57	2·86	3·15	3·43	3·72	4·01	4·29	4·58
$1\frac{1}{2}$	1·25	1·56	1·87	2·18	2·50	2·81	3·12	3·43	3·75	4·06	4·37	4·68	5·
$1\frac{5}{8}$	1·35	1·69	2·03	2·36	2·70	3·04	3·38	3·72	4·06	4·40	4·73	5·07	5·41
$1\frac{3}{4}$	1·45	1·82	2·18	2·55	2·91	3·28	3·64	4·01	4·37	4·73	5·10	5·46	5·83
$1\frac{7}{8}$	1·56	1·95	2·34	2·73	3·12	3·51	3·90	4·29	4·68	5·07	5·46	5·85	6·25
2	1·66	2·08	2·50	2·91	3·33	3·75	4·16	4·58	5·	5·41	5·83	6·25	6·66
$2\frac{1}{8}$	1·77	2·21	2·65	3·09	3·54	3·98	4·42	4·86	5·31	5·75	6·19	6·64	7·08
$2\frac{1}{4}$	1·87	2·34	2·81	3·28	3·75	4·21	4·68	5·15	5·62	6·09	6·56	7·03	7·50
$2\frac{3}{8}$	1·97	2·47	2·96	3·46	3·95	4·45	4·94	5·44	5·93	6·43	6·92	7·42	7·91
$2\frac{1}{2}$	2·08	2·60	3·12	3·64	4·16	4·68	5·20	5·72	6·25	6·77	7·29	7·81	8·33
$2\frac{5}{8}$	2·18	2·73	3·28	3·82	4·37	4·92	5·46	6·01	6·56	7·10	7·65	8·20	8·75
$2\frac{3}{4}$	2·29	2·86	3·43	4·01	4·58	5·15	5·72	6·30	6·87	7·44	8·02	8·59	9·16
$2\frac{7}{8}$	2·39	2·99	3·59	4·19	4·79	5·39	5·98	6·58	7·18	7·78	8·38	8·98	9·58
3	2·50	3·12	3·75	4·37	5·	5·62	6·25	6·87	7·50	8·12	8·75	9·37	10·

N.B.—To ascertain the weights of larger sizes take the half size of that required and double it.

Thus, 4 × 1 in refer to 2 × 1 = 6·66 × 2 = 13·32 lbs.

Plate or Sheet Iron, Brass, Copper, and Lead.
Weight of a superficial foot in Pounds Avordupois.

Thickness in parts of an inch.	Iron. lbs.	Brass. lbs.	Copper. lbs.	Lead. lbs.	Thickness in parts of an inch.	Iron. lbs.	Brass. lbs.	Copper. lbs.	Lead. lbs.
1/16 in.	2·5	2·7	2·9	3·7	7/16 in.	17·5	19·	20·3	25·9
1/8 ,,	5·	5·5	5·8	7·4	1/2 ,,	20·	21·8	23·2	29·6
3/16 ,,	7·5	8·2	8·7	11·1	5/8 ,,	25·	27·1	28·9	37·
1/4 ,,	10·	10·9	11·6	14·8	3/4 ,,	30·	32·5	34·7	44·4
5/16 ,,	12·5	13·6	14·5	18·5	7/8 ,,	35·	37·9	40·4	57·8
3/8 ,,	15·	16·3	17·4	22·2	1 ,,	40·	43·3	46·2	59·2

Thickness of same by the Birmingham Wire Gauge, and in Decimals.

Wire Gauge. No.	Thickness in Decimals of an inch.	Iron. lbs.	Brass lbs.	Copper. lbs.	Wire Gauge. No.	Thickness in Decimals of an inch.	Iron. lbs.	Brass lbs.	Copper. lbs.
0000·	·454	18·99	21·11	21·61	11	·120	5·	5·5	5·8
000·	·425	17·78	19·76	20·53	12	·109	4·38	4·81	5·08
00·	·380	15·89	17·67	18·37	13	·095	3·75	4·12	4·34
0·	·340	14·22	15·81	16·43	14	·083	3·12	3·43	3·6
1	·300	12· 5	13·75	14·5	15	·072	2·82	3·1	3·27
2	·284	12·	13·2	13·9	16	·065	2·5	2·75	2·9
3	·259	11·	12·1	12·75	17	·058	2·18	2·4	2·52
4	·238	10·	11·	11·6	18	·049	1·86	2·04	2·15
5	·220	8·74	9·61	10·1	19	·042	1·7	1·87	1·97
6	·203	8·12	8·93	9·4	20	·035	1·54	1·69	1·78
7	·180	7·5	8·25	8·7	21	·032	1·1	1·54	1·62
8	·165	6·86	7·54	7·9	22	·028	1·25	1·37	1·45
9	·148	6·24	6·86	7·2	23	·025	1·12	1·23	1·3
10	·134	5·62	6·18	6·5	24	·022	1·	1·1	1·16

Hoop Iron. Weight of 10 lineal feet.

Width in inches and parts..	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
No. of gauge	21	20	19	18	17	16	15	14	13	12
Weight in lbs.	·685	·885	1·24	1·60	2·05	2·73	3·40	3·72	4·72	6·06

Comparative Weight of Bar and Cast Iron and other Metals.
Bar Iron, Cast Iron, Steel, Copper, Brass, Lead.

Bar Iron being 1 ..	1·	·95	1·02	1·16	1·09	1·48
Cast Iron being 1 ..	1·07	1·00	1·08	1·21	1·16	1·56

Cast Iron Plate. Weight of a superficial foot.

Thickness in inches.	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
Weight in Pounds.	9·37	14·06	18·75	23·43	28·12	32·81	37·50	46·87	56·25	65·62	75

BALLS.—CAST IRON, COPPER, AND LEAD.

Diam. in Ins.	Cast Iron. lbs.	Brass. lbs.	Copper. lbs.	Lead. lbs.	Diam. in Ins.	Cast Iron. lbs.	Brass. lbs.	Copper. lbs.	Lead. lbs.
1	·136	·158	·166	·214	7	46·76	54·5	57·1	73·7
1½	·46	·537	·56	·727	7½	57·52	67·11	70·0	90·0
2	1·09	1·25	1·3	1·7	8	69·81	81·4	85·2	110·1
2½	2·13	2·50	2·60	3·35	8½	83·73	100·0	102·3	132·3
3	3·68	4·3	4·5	5·8	9	99·4	115·9	121·3	156·7
3½	5·84	6·82	7·14	9·23	9½	116·9	136·4	143·0	184·7
4	8·72	10·2	10·7	13·8	10	136·35	159·0	166·4	215·0
4½	12·42	14·5	15·25	19·6	10½	157·84	184·0	193·0	250·0
5	17·04	19·9	20·8	26·9	11	181·48	211·8	221·8	286·7
5½	22·68	26·47	27·74	36·0	11½	207·37	242·0	253·5	327·7
6	29·45	34·3	35·9	46·4	12	235·62	275·0	288·1	372·3
6½	37·44	43·67	45·76	59·13					

WEIGHT OF NAILS.

Cut Clasp Nails.

		lbs.	oz.
No. 100.	1 inch long. ..	0	2
,, ,,	1¼ ,, ,, ..	0	4
,, ,,	1½ ,, ,, ..	0	6
,, ,,	2 ,, ,, ..	0	12
,, ,,	2½ ,, ,, ..	1	2
,, ,,	3 ,, ,, ..	1	12
,, ,,	3½ ,, ,, ..	2	12
,, ,,	4 ,, ,, ..	4	0
,, ,,	5 ,, ,, ..	7	2
,, ,,	6 ,, ,, ..	9	8

Patent fine wrought Clasp Nails.

		lbs.	oz.
No. 100.	1½ inch long. ..	0	6
,, ,,	1¾ ,, ,, ..	0	8
,, ,,	2 ,, ,, ..	0	11
,, ,,	2½ ,, ,, ..	0	15
,, ,,	3 ,, ,, ..	1	7

Floor Brads.

		lbs.	oz.
No. 100.	2 inch. long. ..	1	1
,, ,,	2¼ ,, ,, ..	1	2
,, ,,	2½ ,, ,, ..	1	8
,, ,,	3 ,, ,, ..	2	0
,, ,,	3½ ,, ,, ..	3	4

Slate Nails.

		lbs.	oz.
No. 100.	1¾ in. long, zinc...	0	13
,, ,,	1½ ,, ,, copper.	0	10
,, ,,	1¾ ,, ,, ,,	0	12

Wrought Barrow Nails.

		lbs.	oz.	
No. 100.	1½ inch long...	0	8	4d.
,, ,,	2 ,, ,, ..	0	12	6d.
,, ,,	2¼ ,, ,, ..	1	2	8d.
,, ,,	2¾ ,, ,, ..	1	8	10d.

Clout Felt Nails.

		lbs.	oz.
No. 100.	1 inch long...	0	6

Lath Nails.

		lbs.	oz.
No. 100.	1 inch long...	0	4½

Wrought Spikes.

		lbs.	oz.
No. 10.	7 inch. long...	2	10
,, ,,	8 ,, ,, ..	3	6
,, ,,	10 ,, ,, ..	5	0
,, ,,	12 ,, ,, ..	7	8

MEMORANDA.

HEATING BY HOT WATER.

100 ft. lineal of 4-inch piping takes from 2·3 to 4·7 lbs. of fuel in an hour.

Four square feet of furnace exposed to the direct action of the fire will heat 200 feet of 4-inch pipe. The area of furnace bars should be 50 square inches to every 100 feet lineal of 4-inch piping.

To reach 50° to 55° of heat will take 5 to 6 feet of 4-inch pipe for manufactories.

To reach 55° to 60° of heat will take 7 to 8 feet of 4-inch pipe for halls, waiting rooms, &c.

To reach 55° of heat will take 35 feet of 4-inch pipe for greenhouses and conservatories.

To reach 65° to 70° of heat will take 45 feet of 4-inch pipe for graperies and stove houses.

To reach 70° to 75° of heat will take 50 feet of 4-inch pipe for graperies and stove houses.

To reach 80° of heat will take 50 feet of 4-inch pipe for pineries and hothouses.

Let the flow pipe on the boiler be about 16 inches higher than the return pipe, or when they are required to sink below the level of the boiler, as in doorways, for instance, let the flow pipe be just as much higher in addition to the 16 inches in proportion.

Where it is thus necessary to increase the height of the flow pipe above the boiler let, it be done at once directly on leaving the boiler, as it increases the circulation.

Cast-iron piping will expand when heated about 1½ inches in every 100 feet, and therefore when long straight lengths are used they

ought to be provided with $\frac{5}{8}$ or $\frac{3}{4}$ inch round bars, laid loose on bricks to support the pipe as rollers, to assist in the expansion or contraction. The lower the boiler, or the higher the pipe is carried short of 30 feet the more rapid the circulation.

Let the supply cistern be cubical, and place it above the level of the highest point of the apparatus. It should contain $\frac{1}{30}$ of the whole contents of the boiler and pipes. Always form a syphon of the connecting pipe, and join it to the lowest or return pipe.

100 feet of	$\frac{1}{2}$	inch pipe contains	·84	gallons of	water.
,,	1·	,,	3·39	,,	,,
,,	$1\frac{1}{2}$	,,	7·64	,,	,,
,,	2	,,	13·58	,,	,,
,,	$2\frac{1}{2}$	,,	21·22	,,	,,
,,	3	,,	30·56	,,	,,
,,	4	,,	54·33	,,	,,

Air vents must be provided to the highest part of the apparatus, or wherever the air is likely to lodge, as for instance where there are dips or bends.

When the circulation requires to be stopped off at any part of the pipe—say from one house to the other—use stop-cocks one-half less than the size of the pipe (that is, for 4-inch pipes use a 2-inch stop-cock) in both the flow and return pipes.

Maximum heat will be attained in about as many hours as there are inches in the diameter of the pipe.

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